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# THESIS

MISSILE EMPLOYMENT FROM FAST PATROL BOATS.
COMPUTER-BASED ANALYSIS OF THE
SEARCH-SECTOR PARAMETERS

by

Bernd Lehmann
Lieutenant Commander, Federal German Navy

June 1977

Thesis Advisor: D. E. Harrison

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The objective of this computer-based analysis is to investigate the effect of target evasive maneuvers on the probability of acquisition by the seeker of the surface-to-surface missile MM 38 "Exocet" employed from Federal German Navy Fast Patrol Boats. Two different targeting methods, the unassisted and the assisted (by helicopter or remotely piloted vehicle) are analyzed with respect to the dependence of the probability of acquisition upon sensor capabilities, missile characteristics, and the motion of the target, in

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particular the interdependence between the various missile search-sector parameters, the target range, and the target aspect-angle. The influence of the radar cross-section at different aspect-angles of the various Warsaw Pact Navy surface vessels are not considered in this unclassified analysis. The most effective measures to significantly improve the probability of acquisition are the shift of the point of aim and the minimization of the target reaction-time.

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# MISSILE EMPLOYMENT FROM FAST PATROL BOATS• A COMPUTER-BASED ANALYSIS OF THE SEARCH-SECTOR PARAMETERS

by

Bernd Lehmann
Lieutenant Commander, Federal German Navy

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL

June 1977

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# I. INTRODUCTION

## A. OBJECTIVES OF THE ANALYSIS

This computer-based analysis provides preliminary tactical recommendations for the employment of the MM 38 "EXOCET" Surface-to-Surface-Missile (SSM) from Federal German Navy ( FGN ) Fast Patrol Boats (FPBG) Class 143 (10 boats) and Class 148 (20 boats). These boats have a displacement of less than 400 tons, and their main operation area is the Baltic Sea and its approaches.

The successful employment of a missile against a target is primarily dependent on its target-aquisition (TA) capability, measured by the probability of acquisition (PA). A significant characteristic of any SSM of the present generation is, that due to the technological limitations, its seeker can not discriminate between several targets in the assigned search-area.

The solution of the problem of target-discrimination (TD) - the seeker acquires only the selected target - is very desirable in multiship naval engagements. TD can be improved by decreasing the search area of the missile, but this also decreases the probability that the desired target will be acquired, a result which normally can not be accepted.

These two competing requirements, TA and TD, require a thorough investigation of the various missile search-sector

parameters' influence on the targeting-scheme chosen in an assumed tactical scenario.

The search-sector area, which is defined by three variable parameters, must

1. ensure a PA of 0.99 - a specification required by the FGN. The very high probability is chosen to compensate for uncertainties of the system reliability and target-data related errors like course and speed, range and bearing. This requirement results in maximizing the possible search-sector area with the consequence that almost all target discrimination is lost.

2. achieve an improved target discrimination. This requirement can be achieved by minimizing the search-sector area.

3. prevent premature detection and identification of own missiles in flight and therefore minimize effective enemy Anti-Ship-Missile-Defense (ASMD). This can be only achieved by minimizing the missile seeker activation-distance, which would decrease the actual search-area, and thereby improve the target discrimination.

In the view of these three requirements, the analysis investigates the dependence of PA upon sensor capabilities, missile characteristics, and the motion of the target, in particular the interdependence between the various search-sector parameters, the target range, and the target aspect-angle. Eight hypotheses with respect to TA and TD result from "improvement-considerations":

1. Target-Acquisition (TA)

(1) TA can be improved by reducing the missile launching-distance.

(2) TA can be improved by a proper choice of the aspect-angle to the target.

(3) TA can be improved by shifting the aim-point in the direction of the expected target-motion.

(4) TA can be improved by any combination of (1), (2), and (3).

2. Target-Discrimination (TD)

(5) TD can be improved by reducing the missile seeker activation-distance,

(6) TD can be improved by reducing the missile-scan-angle.

(7) TD can be improved by reducing the missile-seeker search-depth.

(8) TD can be improved by any combination of (5),(6) and/or (7).

Although TD considerations will be included where appropriate, this analysis deals with one-on-one scenarios, and the multiship-engagement is not analyzed.

## B. PRESENTATION OF THE TARGETING-SCHEMES

The analysis examines two scenarios which correspond to two anticipated targeting-schemes:

* Unassisted Targeting ( UAT ),

* Over-the-Horizon Targeting ( OTH ).

Fig 1 depicts these two schemes.

1. UAT - The single ellipse in the first box indicates that UAT has one source of targeting error - the launch-platfcrm's sensor error. The attack range is limited to the line-of-sight horizon.

2. OTH - This procedure has an additional source of error - the uncertainty of position of the extended platform - which also contributes to the final target position error. The upper bound for the attack range is the missile range itself.

The computer simulations are similar, and share many common features, but the OTH analysis is more complex. In each case the engagement is followed until the missile is in position to achieve Lock-on. Target ASMD-options other than maneuvers are not considered; it is assumed that the target accelerates to maximum speed when aware of the "threat" and maneuvers in a fashion to evade the missile seeker search area.

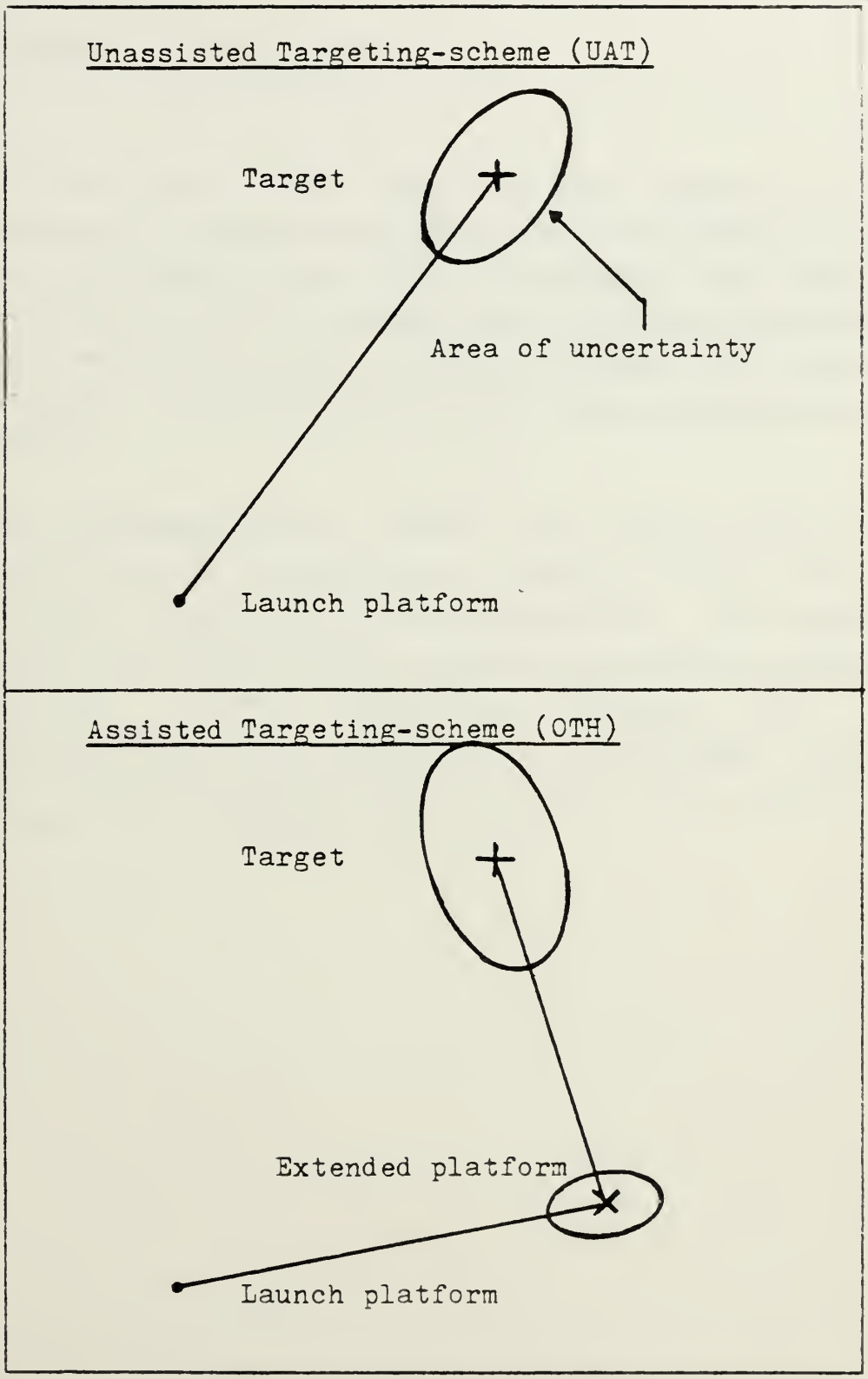



Figure 1 - TARGETING-SCHEMES

## C. PATTERN OF THE ANALYSIS

A description of the related weapon systems and the introduction of relevant variables for the simulation, based on the performance characteristics, precedes the statement of necessary general assumptions, targeting requirements, and the evaluation of the targeting-schemes as one-on-one engagements. Finally, conclusions and recommendations are presented.

The recommendations reflect only generalized scenario situations due to a supression of complete data about own and hostile forces and their capabilities. Two appendices illustrate the target-motion analysis and sensor performance prediction. The simulation models for both targeting-schemes are provided as a computer printout. Results and recommendations for the real systems are available as a classified appendix.

## II. DESCRIPTION OF RELATED WEAPONS-SYSTEMS

The performance characteristics of the three weapon systems and their degree of sensitivity dominate the successful missile employment. Relevant variables are introduced to describe and represent these characteristics in the simulation models for both targeting-schemes.

### A. FPBG-CLASSES 143/148

These two FPBG-Classes are the launch platforms for the missile MM 38 in both targeting-schemes; there is no distinction between their different capabilities in the simulation model.

#### 1. Technical Data

Both classes have a displacement hull-design, and their propulsion-system consists of four diesels delivering a total of 16000 HP (143), 12000 HP (148).

The armament of Class 143 consists of

-Four SNIAS MM38 EXOCET missiles

-Two 76 mm OTO-MELARA general-purpose gun mounts

-Two tubes with wire-guided torpedoes

The armament of Class 148 is similar to that of

Class 143 and consists of

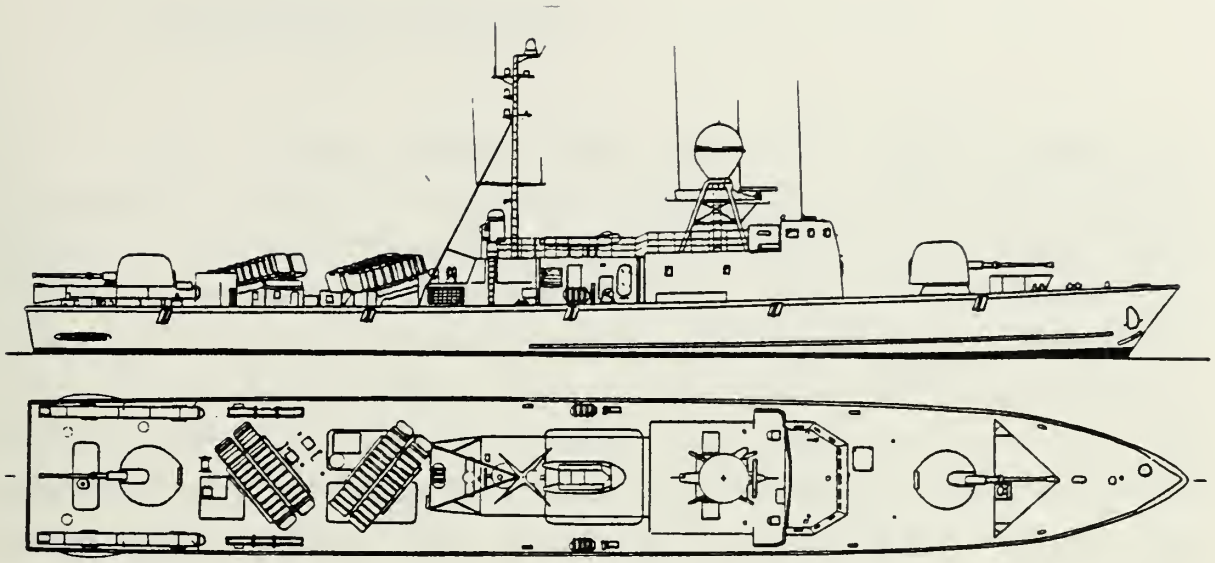
-Four SNIAS MM38 EXOCET missiles

-One 76 mm OTO-MELARA general-purpose gun mount

-One 40 mm BOFORS anti-aircraft gun

-Eight mines

The Class 143 carries a fully integrated command and fire-control system - data automation system AGIS. Target data can be almost immediately analyzed by AGIS, a capability, which is not provided on the Class 148 [1].



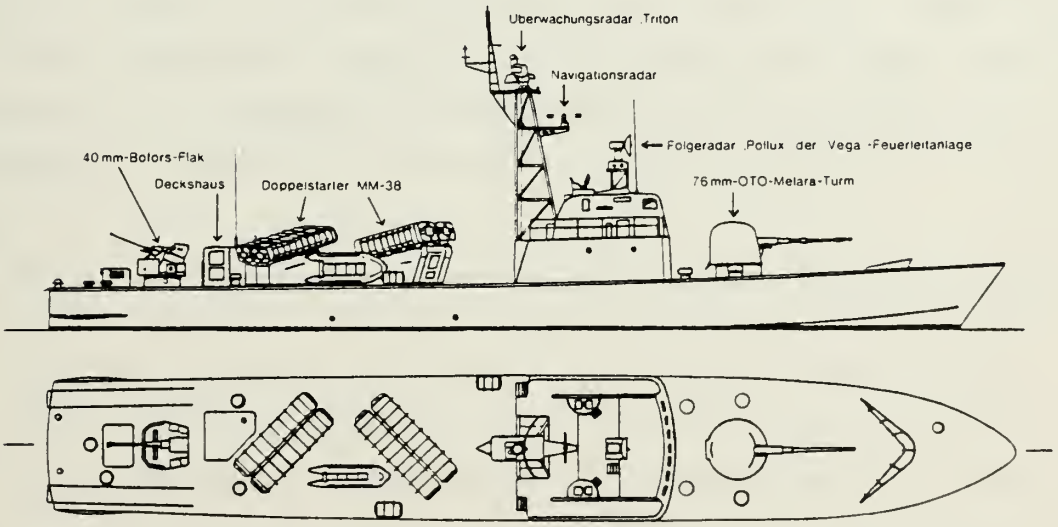



Figure 2 - FPBG CLASSES 143/148

## 2. Performance Variables

At least intermittent use of active radar is required to provide reliable target-data. The performance data of the active sensors are pertinent for the simulation model. The surface search radar on both FPBG-Classes is used to detect the target and to obtain further target data; its use is suggested for the unassisted targeting-scheme. The assisted targeting-scheme requires the use of the fire-control radar to establish a radar-fix on the extended platform. Target data evaluation is performed without the use of AGIS, which results in a degraded quality of the data - larger inaccuracy - and in an increase of the delaytime. The bearing and range errors are normally distributed random variables with mean-values of 0 and standard deviations (SIGBL, SIGRL) of 0.25° and 120 m respectively. The errors in the evaluated target data for course and speed are also assumed to be normally distributed with mean-values of 0 and respective standard deviations (SIGCL, SIGSL) of 3.5° and 0.4 kts.

$\sigma_{BL}$ = standard deviation of the sensor bearing error,

$\sigma_{RL}$ = standard deviation of the sensor range error,

$\sigma_{CL}$ = standard deviation of the target-course error, and

$\sigma_{SL}$ = standard deviation of the target-speed error.

## B. EXTENDED PLATFORM

In this analysis extended platforms are considered to be either a helicopter (HC) or a remotely piloted vehicle (RPV). Both are means to extend the "information-range" of the launch platform, which is limited to the radar horizon without this support.

At the present time the FGN deploys only the land-based "Seaking" Mk 41 HC in its Search and Rescue-version. Until the introduction of a HC or RPV more suitable for this purpose it is reasonable to assume that the present HC might be used as an extended platform in cooperation with the FPBG-force, if appropiate conditions - geographical factors as well as the degree of air-threat - prevail. Because no suitable HC is presently being procured, detailed performance data are not available.Here the technical description of the HC are characteristics of the "Seaking" Mk 41 and the "Lamps" Mk 2. Electronic/optronic detection and communications are postulated. The HC or the RPV is used as a "Third Party" for the assisted targeting-scheme.

### 1. Performance Variables

The sensor performance data are also the standard deviations (SIGBE, SIGRE) of the normally distributed random errors in bearing and range. The mean-values of these errors are also assumed to be 0. The sensor inaccuracies will be 30 m in range, and from 1° to 3° in bearing.The target data for course and speed, which are a combination of measurement and human evaluation, contain errors which are also assumed to be normally distributed with mean-values of

0 and standard deviations (SIGCE, SIGSE) of 5° and 1.5 kts.

$\sigma_{BE}$ = standard deviation of the sensor bearing error,

$\sigma_{RE}$ = standard deviation of the sensor range error,

$\sigma_{CE}$ = standard deviation of the target-course error, and

$\sigma_{SE}$ = standard deviation of the target-speed error.

$\sigma_{BL}$, $\sigma_{BE}$, $\sigma_{RL}$, and $\sigma_{RE}$ are solely sensor-related. whereas $\sigma_{CL}$, $\sigma_{CE}$, $\sigma_{SL}$, and $\sigma_{SE}$ have an additional error due to human performance for the 148-Class boats, and, in the case of the use of an extended platform, because these two data sets are not directly evaluated by AGIS.

## C. MM 38 "EXOCET" MISSILE-SYSTEM

The following technical presentation of this SSM and the trajectory description in the vertical and horizontal plane was partially drawn from an unclassified report [2]. It provides a good presentation of the general trajectory characteristics of the MM 38.

### 1. Technical Data

The missile was developped in the late sixties, and its first successful launch was recorded in June 1971. The air-tight container, in which the missile is stored, also serves as the launcher. The warhead is a classic fragmentation type with blast effect and a weight of 165 kg; it has a delayed impact fuze and a proximity fuze controlled by the autopilot.

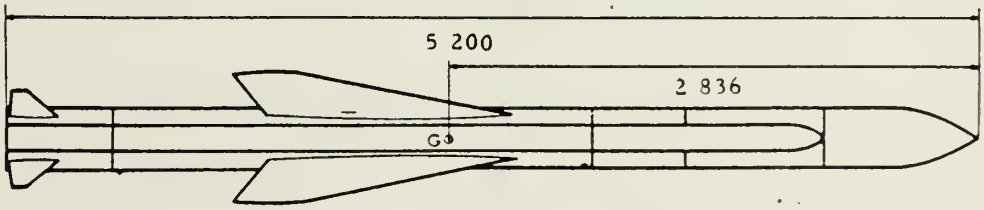



Figure 3 - MM 38 EXOCET-SSM

The missile with its sea-skimming trajectory has a maximum range of 22.7 nm (42000 m), a practical range of 20.5 nm (38000 m), and a minimum range of 2.5 nm (4500 m). Its cruise speed is specified as 315 m/sec (Mach 0.93), The midcourse flight altitude is 10-15 m, the final phase altitude is 2-5 m. The trajectory launch-phase covers about 2.2 nm (4000 m), the midcourse phase about 11.9 nm (22000 m), and the final phase about 6.4 nm (12000 m). Target information is normally provided by radar (active/passive), but visual bearing and estimated range can be set manually.

The variable size of the search-area is primarily dependent on 3 different parameters, which have to be determined/set before launch:

- Missile seeker-activation-distance ACTIV (m), related to the target-distance at launch-time,

- Missile seeker-scan-angle ± PHI (deg), centered on the point-of-aim (POA), and

- Missile seeker-search-depth ± L (m), related to the target-distance at launch-time.

The parameter-settings are assumed as follows:

- small (K), and

- large (G).

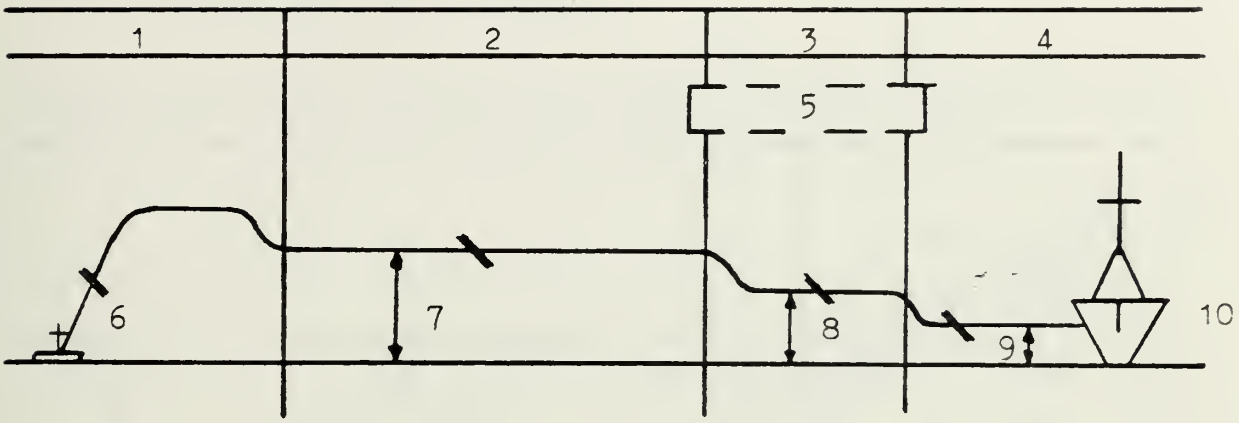
The resulting parameter combinations are KKK, KKG, KGK, and KGG for the small activation-distance, and GKK, GKG, GGK, and GGG for the large activation-distance. The second letter refers to the scan-angle, and the third letter determines the size of the search-depth. Additionally, the search-sector size is dependent on the lobe-width of the missile radar.

## 2. The Missile Trajectory

It should be pointed out that the following description of the missile trajectory reflects a particular parameter combination which is necessary to assure a very high PA. The homing-head search-area is always ground-stabilized, and adjusted in size to cover aiming and system errors and to allow for almost all possible target-motions. The largest values of all adjustable parameters assure a large PA, but lead to very poor TD.

### a. The Vertical Missile Trajectory

For the following description refer to Fig 4. At the end of the launch phase the missile is stabilized in the direction of the target at the midcourse altitude H1. This altitude H1 satisfies a dual requirement: while being low enough to avoid detection by the target until the missile is a given distance from it, the missile is still high enough to allow its seeker head to rapidly acquire the target after activation. At the end of the midcourse phase, the missile descends to an altitude (H2<H1), chosen to meet the same requirements as H1 but at a shorter distance from the target. Finally, the missile covers the final approach phase at the lowest altitude (H3<H2) permitted by the sea state. The search phase, which follows the activation of the seeker head, can take place either at the end of the midcourse phase, or during the approach phase, depending on the launch range. Normally the altitude H3 guarantees the impact on the target, otherwise the proximity fuze will detonate.



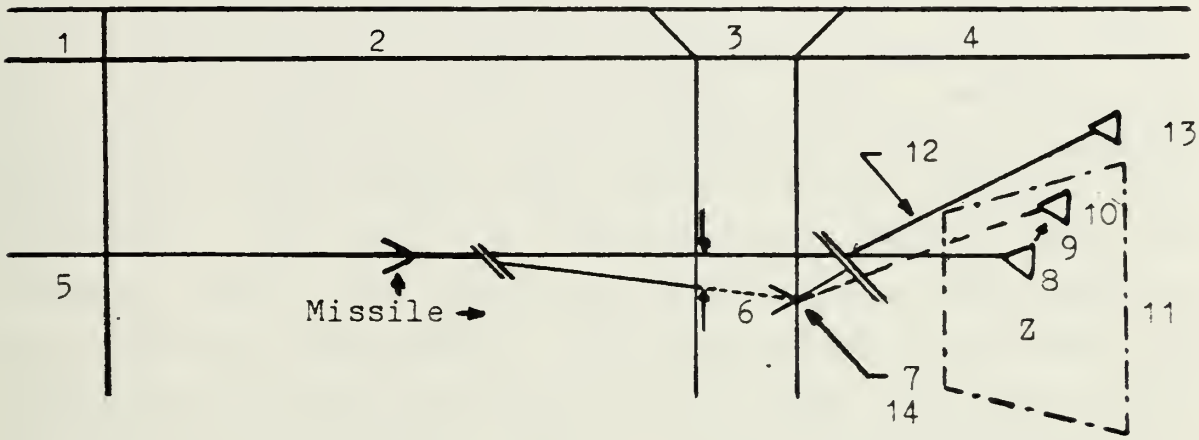

1-Launch phase 2-Midcourse phase 3-Initial approach phase
4-Final approach phase 5-Search phase localization zone
6-Launch platform 7-H1 8-H2 9-H3 10-Target

Figure 4 - MISSILE TRAJECTORY IN THE VERTICAL PLANE

b. The Horizontal Missile Trajectory

For the following description refer to Fig 5. The horizontal trajectory shows that the missile flies (at altitude H1) towards the target's position B1, which is designated at the instant of launching. Regardless of the surface wind, the missile's inertial platform maintains it on its path to a within a small error, until the end of the midcourse phase. At a given distance, D, from B1, the seeker is activated, and sweeps a predeterimined zone, Z, sufficient to compensate for any navigational errors, any launching errors in target designation, and particularly any changes in the target's course during the missile flight. The target is detected at B3, at the end of a short search phase. Immediately, there is an exchange of data between the seeker and the inertial platform to determine the target's motion, counter any possible maneuvers, overcome

any ECM, and under the surveillance of the radar altimeter, choose the best point of impact.




1-Launch phase 2-Midcourse phase 3-Search phase
4-Homing phase 5-Launch platform 6-Error
7-Detection 8-B1 9-B2 10-B3 11-Search pattern
12-Homing 13-Actual target position 14-Activation distance

Figure 5 - MISSILE TRAJECTORY IN THE HORIZONTAL PLANE

## 3. Performance Variables

The search parameter settings - chosen just before the actual launch - are constants; they reflect the evaluated target-data. Wind direction and speed are both variables, established just prior to the launch, and therefore are built as deterministic values into the computer model. The choice of the activation time dominates the missile performance. When activation is delayed, the target has a greater time in which to react, and the PA of the system is degraded. Prior to the actual missile launch, a time of 12 sec is necessary for the missile gyro stabilisation (MISRED). This delay is included in the assisted targeting-scheme. The unassisted targeting-scheme simulation is initiated with the launch command. It takes 2.5 sec ($T_{LAUN}$) on an average, until the missile has actually left the launcher.

The missile speed of 315 m/sec plus a normally distributed random variable with a mean-value of 0 and a standard deviation (SIGVM) of 1.5 m/sec determines the flight time until the expected Lock-on. This flight time can be influenced by the downrange component of the prevailing wind.

The missile seeker will be activated at the preprogrammed activation-distance, and it is fully operational after 3 sec ($T_{OP}$). The search for the target is terminated with the Lock-on of the homing head which occurs after 0.4 sec or 2.4 sec ($T_{SCAN}$) as a function of the choice

of the scan-angle, PHI, the number of scans necessary to lock-on, and the scan-speed of the seeker. It is evident that this delay caused by $T_{OP}$ and $T_{SCAN}$ will significantly influence the size of the actual search area. These three defined times are summed to the variable $T_{DEL}$, which has a value of 5.90 sec or 7.90 sec, dependent on the scan-angle PHI.

The actual missile flight-time ($T_{FLIT}$) until the Lock-on is a function of the target range and the actual missile speed, the selected activation-distance, and the scan-angle. The actual Time of Lock-on ($T_{LOCK}$) is given by

$$T_{LOCK} = T_{FLIT} + T_{LAUN}.$$

The value of $T_{LOCK}$ also determines the navigation error of the missile, which is circular normally distributed with a mean-value of 0 and a standard deviation (SLOKB, SLOKR) of $T_{LOCK}$*1.62 m/sec.

# III. GENERAL ASSUMPTIONS

Due to the number of factors involved in a complete "time development" from the first detection of enemy units, their classification, the decision to engage with missiles until the actual missile impact on the selected target, assumptions are necessary to simplify the simulation and the resulting analysis. These assumptions cannot oversimplify; the simulation must remain credible. To avoid any obvious bias by overemphasizing some factors (i.e. abnormal ducting conditions, heavy sea-state, stationary target), and to obtain an insight into the significance of the different factors, a standard scenario was built. This includes assumptions concerning environmental factors as well as tactical factors which describe the behavior of both own and hostile forces. It seems to be evident, that with the knowledge of the significance of the factors any actual deviation from the standard scenario can be thoroughly evaluated for its influence on the missile employment.

## A. ENVIRONMENTAL FACTORS

Environmental factors influence the planning and execution of surface warfare operations. They may help or hinder the platforms, the sensors, and weapons; they include

- Meteorological Factors,
- Oceanographical Factors,
- Ionospheric Factors, and

- Geographical Factors.

The following assumptions were made:

- System performance is not degraded until sea-state is reached.

- Wind-direction: 300 degrees.

- Wind-speed: 0.0 m/sec, or 7.7 m/sec (15 kts).

- Detection range is limited by the radar horizon (line of sight); no surface radar ducting conditions. Relevant detection ranges of FGN FPGB-units against prospective WPN Surface-units are provided in Appendix B which also includes assumptions about hostile detection ranges against the MM 38 missile. The wind speed was included in the computer simulation, but preliminary analysis of the output indicated that at these speeds its effect is neglible.

## B. TACTICAL CONDITIONS ASSUMED FOR OWN FORCES

The most important factors of this group refer to the "time develcpment" of the missile employment for either targeting-scheme. The following assumptions were made:

- System reliability of 1.0 for all components on board the launch-platform/HC/RPV.

- Time development for the unassisted targeting-scheme extends from the actual launch-command ( all necessary data were already fed intc the missile computer ) until the final Lock-on of the missile on the selected target.

- HC/RPV availability without delay, if necessary.

- Time development for the assisted targeting-scheme extends from the target-data report by HC/RPV to the launch-platform until the final Lock-on of the missile on the selected target. This procedure will be more inaccurate due to the greater time-delay and because different sensor-types are required.

- No distinction in capabilities between FPEG-Classes.

## C. TACTICAL CONDITIONS ASSUMED FOR HOSTILE FORCES

This group of factors depends on the characteristics of various types of Warsaw-Pact Navy (WPN)-Forces, and the countermeasures available to each vessel.

### 1. Enemy Surface-Combattants

For the one-on-one engagement four target-types were chosen:

- 1.Guided missile destroyer (DDG) : Krivak-Class
- 2.Guided missile corvette (PFG) .: Nanuchka-Class
- 3.Guided missile FPB (FPBG) .....: Osa-Class
- 4.Amphibious ship (LSM) .....: Polnocny-Class

Detailed descriptions of these different surface-ship types are provided in [3].

2. Enemy Reaction-Time

The enemy reaction-time defines a second set of variables, which also significantly contribute to the time development of the launch-sequence; the reaction-time also depends on the type of engagement (UAT/OTH).

For the UAT-scheme, the first variable is the delaytime prior to missile detection (DETDEL), which is a function of the sensor type operated on board the target. The second variable is the delaytime before an actual response can be initiated by evasive maneuvers (TRNDEL).
For the four target types the following mean-values in seconds are assumed for DETDEL and TRNDEL, respectively:

- DDG..: 10/10
- PFG..: 10/10
- FPBG.: 12/8
- LSM..: 15/15

The values for DETDEL assume a high level of maintenance and operator skill, but it is reasonable to believe that the WPN have sophisticated sensors and trained personnel available, which justify these assumptions. The values for TRNDEL are based on personal experience, and also seem applicable to the WPN.

For the OTH-scheme, four delaytimes affect the reaction-time. They are defined as follows:

1.Delaytime due to transmission of the enemy contact report (RELAY) from the H/C to the launch-platform.

2.Delaytime onboard the launch-platform for the evaluation of the transmitted target data (DELEVA).

3.Delaytime due to missile gyro stabilisation, necessary for the launch (MISRED), and the

4.Delaytime TRNDEL.

The delaytime DETDEL, defined for the UAT-scheme, is included in the three delaytimes RELAY, DELEVA, and MISRED, because it is reasonable to assume, that the HC and/or its UHF-transmission will be detected by the target and interpreted as an imminent SSM attack. Therefore this time-variable is discarded in this targeting-scheme.
The respective times in seconds are

- RELAY..: 10
- DELEVA.: 10
- MISRED.: 12
- TRNDEL.: equivalent to the UAT-scheme.

The reaction-time is also assumed to be normally distributed with mean-value formed by the sum of the respective delaytimes, and the standard deviation $\sigma_{Del}$ of 1.5 sec. This reaction-time (REACT) is further influenced by the detection-range of the WPN surface-combattants against the attacking missile. Appendix B provides the pertinent data, defined as RNG5. If the range to the target is less than the given values, the reaction-time (the time from the first detection until the attacked ship actually starts changing its motion by maneuvring) keeps its original value. If this range is larger than the limiting value, an additional time is obtained by dividing the difference (actual range - RNG5) by the missile speed, and adding the result to the original value of REACT. Until this time the target course and speed are assumed to remain constant.

### 3. Enemy Countermeasures

The analysis is based on the "worst case" assumption, namely, that the enemy forces have available and in operation appropiate electronic or infrared support measures to detect characteristic FC-radar emissions and/or attacking missiles. Under these conditions the missile attack might be detected as early as 10 seconds after the launch (DETDEL). This time includes the sensor-system lag-time as well as the human reaction-time, until the required counter action is taken. These sensors require line-of-sight conditions, and are limited by the radar-horizon. The maximum range at which a target can be detected depends on the sensor height and target height.

Once a threat radar or the missile-launch has been detected, the enemy forces initiate suitable defensive measures to counter the attack. In addition to the alteration of speed and course considered in this analysis electronic warfare (EW) countermeasures are also to be expected.

#### a. Speed/Course-Changes

Some of the target vessels have a gas-turbine or high-power diesel propulsion system, which can produce rapid and major speed changes within the expected missile flight-time. This capability combined with maximum course changes is a very effective countermeasure. The search pattern can be evaded if the target can maneuver out of the area pre-programmed into the missile prior to launch. These effects are described in detail in Appendix A "Target-Motion Analysis". Two evasive maneuver options are available to

the target: the "choices" of the turn-direction and of the number of degrees the target intends to turn in the specified direction, before it will straighten to its new course. Each option is an independently generated random event in the simulation. The direction chosen is Bernoulli event, while the angle chosen is uniformly distributed (0°-90°). This is a "best" case assumption from the target's viewpoint, because preliminary analysis also showed that any turning angle greater than 90° reduces its probability of evasion. The model determines the final course from a randomly chosen time variable as a function of the time necessary to turn 90°.

In the UAT-simulation the initial target course is defined as 360°; the target course in the OTH-simualtion is 180°. The target speed change capabilities were taken from [3]:

- DDG..: 14 - 30 kts in 50 sec
- PFG..: 18 - 30 kts in 75 sec
- FPBG.: 18 - 36 kts in 60 sec
- LSM..: 12 - 16 kts in 60 sec.

The first number refers to the target initial speed assumed in the simulation, the second number to the final speed, which can be achieved with maximum acceleration in the time specified by the third number. The simulation investigated the indicated speed capabilities and also analyzed the effect of high initial speed, 28 kts, for the DDG target. The estimated acceleration-data are the same as evaluated above. The response time for course and speed changes (TRNDEL) is assumed to have an average value of approximately 10 sec.

b. Electronic-Warfare

Both passive and active measures are employed to counter the anti-ship missile threat. WPN ships probably have basic informations about NATO sensor-characteristics and relate them to their EW-measures.

Although employment of decoys and active jamming is probable and ASMD with SAMs and rapid-firing guns is certain, this analysis is restricted to enemy countermeasures by speed/course alterations.

## D. SUMMARY OF RELEVANT VARIABLES

Table I lists all variables used in either targeting scenario.

| | |
|---|---|
| **LAUNCH PLATFORM:** | |
| SENSOR BEARING ERROR -SIGBL- (1$\sigma$)....: | 0.25° |
| SENSOR RANGE ERROR -SIGRL- (1$\sigma$).....: | 120 M |
| SENSOR BEARING ERROR (FC) -SIGBLE-...: | 0.14° |
| SENSOR RANGE ERROR (FC) -SIGRLE-.....: | 10 M |
| TARGET COURSE ERROR -SIGCL- (1$\sigma$).....: | 3.5° |
| TARGET SPEED ERROR -SIGSL- (1$\sigma$).....: | 0.4 KN |
| **MISSILE:** | |
| ACTIVATION-DISTANCE K -ACTIV-.....: | 6000 M |
| ACTIVATION-DISTANCE G -ACTIV-.....: | 12000 M |
| SCAN-ANGLE K -PHI-.....: | +/-1.5° |
| SCAN-ANGLE G -PHI-.....: | +/-9.0° |
| LOBEWIDTH -PSI-.....: | 11 |
| SEARCH-DEPTH K -L-.....: | +/-1000 M |
| SEARCH-DEPTH G -L-.....: | +/-2000 M |
| GYRO-STABILISATION -MISREC-.....: | 12.0 SEC |
| LAUNCH-DELAY -TLAUN-.....: | 2.5 SEC |
| SEEKER OPERATIONAL -TOP-.....: | 3.0 SEC |
| SEARCH-TIME UNTIL LOCK-ON K -TSCAN-.: | 0.4 SEC |
| SEARCH-TIME UNTIL LOCK-ON G -TSCAN-.: | 2.4 SEC |
| DETECTION-TIME -DETDEL-.....: | 10-15 SEC |
| RESPONSE-TIME COURSE/SPEED -TRNDEL-..: | 8-15 SEC |
| SPEED -VMISS-.....: | 315 M/SEC |
| STANDARD DEVIATION SPEED -SIGVM-.....: | 1.5 M/SEC |
| STANDARD DEVIATION DELAYTIME -SIGDEL-: | 1.5 SEC |
| STANDARD DEVIATION NAVIGATION -SLOKB-.: | TLOCK*1.62 |
| STANDARD DEVIATION NAVIGATION -SLOKR-.: | TLOCK*1.62 |
| **EXTENDED PLATFORM:** | |
| SENSOR BEARING ERROR -SIGBE- (1$\sigma$)....: | 1.0°-3.0° |
| SENSOR RANGE ERROR -SIGRE- (1$\sigma$).....: | 30 M |
| TARGET COURSE ERROR -SIGCE- (1$\sigma$).....: | 5.0° |
| TARGET SPEED ERROR -SIGSE- (1 ).....: | 1.5 KN |
| **TARGET:** | |
| DETECTION-TIME -DETDEL-.....: | 10-15 SEC |
| RESPONSE-TIME COURSE/SPEED -TRNDEL-..: | 8-15 SEC |
| STANDARD DEVIATION DELAYTIME -SIGDEL-: | 1.5 SEC |

Table I - RELEVANT DATA FOR THE ANALYSIS

# IV. TARGETING REQUIREMENTS

The two major targeting requirements are that the target must be within the attack-range of the missile, and that the crossrange and downrange errors must be sufficiently small, that the missile seeker has a high target-acquisition probability. These requirements apply to both targeting-schemes investigated.

## A. SEARCH-PATTERN DIMENSIONS

As already pointed out, the search-pattern of the "Exocet" missile is a function of the three parameters, the activation-distance ACTIV, the scan-angle PHI, and the search-depth L, each assumed with two different settings, which yield 8 search-pattern combinations. The simulation investigates the possibility that some of the 8 combinations are less useful than others, particularly when TD is a consideration.

Two variables, CR and DR, are determined by these three parameters. CR is defined as the crossrange halfwidth search dimension, measured in (±) meters, and DR is defined as the downrange halfwidth search dimension, also measured in (±) meters.

The search pattern of the seeker is part of an annulus, where CR represents the maximum halfwidth of the sector, and DR the distance from its inner to its outer boundary. The pattern can be approximated by a rectangle with dimensions 2*CR and 2*DR, with the downrange (y)-axis in the launch direction (parallel to DR).

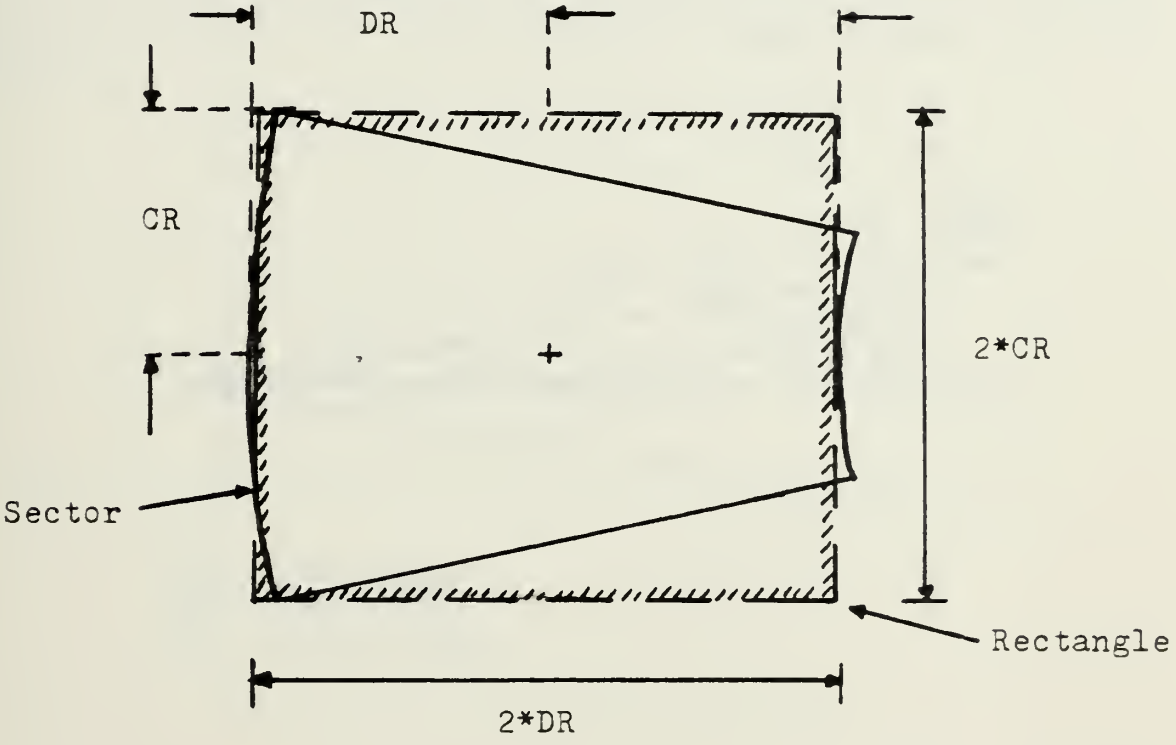
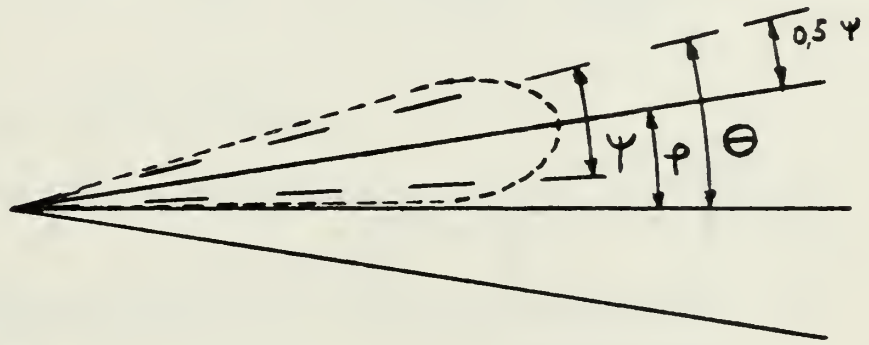



Figure 6 - APPROXIMATION OF THE SEARCH PATTERN

CR is a function of the search-angle, THETA, which is the sum of the scan-angle and half the antenna lobe-width PSI.

Search-angle THETA ( $\vartheta$ ) = ± (PHI + 0.5*PSI)

PSI is the antenna lobewidth with respect to the 3 db-line. Fig 7 shows the relation search-angle/scan-angle for PHI of 9.0° and PSI of 11.0°. The complete search-width is then 29.0°.




$\varphi$ - Scan angle
$\Psi$ - Lobe width
$\vartheta$ - Search angle

Figure 7 - RELATION SEARCH-ANGLE/SCAN-ANGLE

The downrange dimension, DR, is determined by the search-depth, L, chosen in the parameter combination.

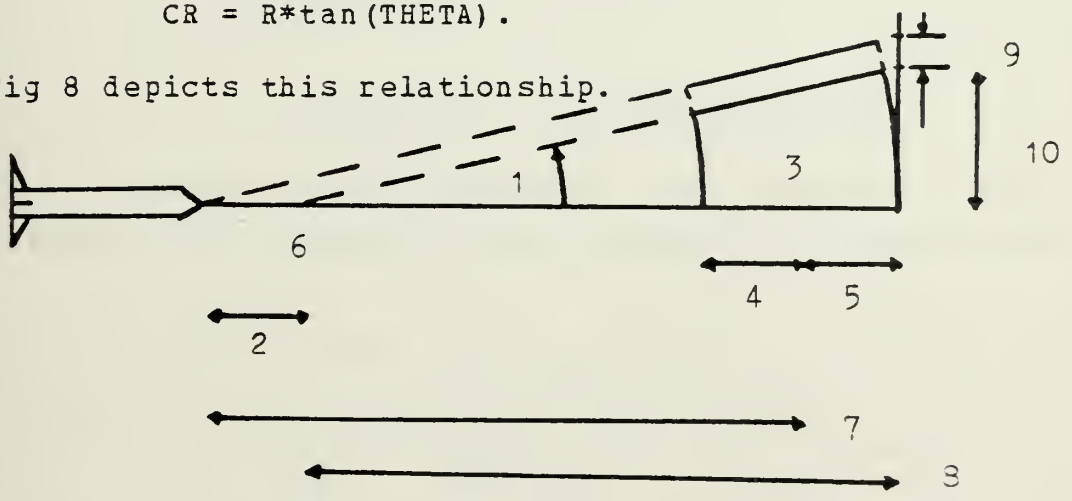
The search pattern is centered on the POA, but angle dependent, which means that its width, CR, reflects the delay by $T_{OP}$; it decreases because the search angle remains constant as the missile approaches the POA. The actual CR-value after 2 complete antenna scans is obtained from the formulas

$$R = (ACTIV + L) - (T_{OP} + T_{SCAN}) * v_{MISS},$$

and

$$CR = R * \tan(THETA).$$

Fig 8 depicts this relationship.




1-Search angle (G) 2-$(T_{OP}+T_{SCAN})*v_{MISS}$ 3-POA

4-(-)L (K) 5-(+)L (K) 6-Missile position after (2)

7-Activation-distance (K) 8-R 9-CR difference due to (2)

10-Actual CR-dimension

Figure 8 - REDUCTION OF THE SEARCH PATTERN

The following table provides CR/DR-dimension values for the "Exocet" search system.

| PARAMETER COMBINATION | CR | DR |
|---|---|---|
| KKK | 718.7 | 1000.0 |
| KKG | 840.6 | 2000.0 |
| KGK | 1318.8 | 1000.0 |
| KGG | 1569.2 | 2000.0 |
| GKK | 1449.9 | 1000.0 |
| GKG | 1571.8 | 2000.0 |
| GGK | 2821.1 | 1000.0 |
| GGG | 3071.5 | 2000.0 |

DIMENSION: M

Table II - CR/DR-DIMENSIONS

In the computer model the search area dimensions, CR and DR, determine the maximum allowed bearing and range errors.

The attack-ranges (launch distance) investigated vary from 14000 m, which is the effective gunnery range for 76 mm caliber, to the radar-horizon range (RP1) characteristic of each target-type. Appendix B provides the detailed derivation of these ranges. The effective RP1-values are approximated as follows:

- DDG..: 32500 m
- PFG..: 29000 m
- FPBG.: 26000 m
- LSM..: 29500 m

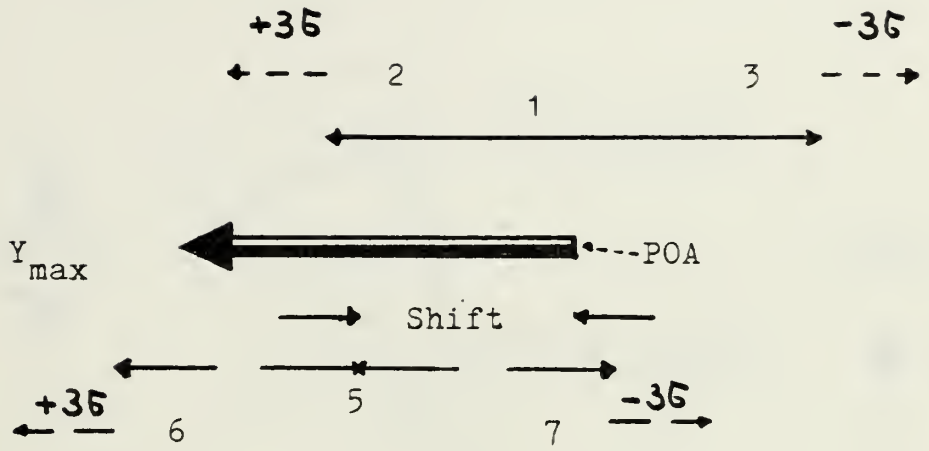
These limits are used in the UAT-simulation. The attack ranges investigated for the OTH-model vary from the characteristic RP1-range up to 40000 m, which exceeds the practical range of the MM 38 missile.

## B. SHIFT OF THE POA

Appendix A "Target-Motion Analysis" reveals that it is unrealistic to assume that the target has no limitations on its course alternatives from its initial course. This perception leads to the idea that the POA should be shifted to a new point which is displaced in the direction of the predicted initial course. This displacement $Y_{max}$ is a function of the estimated target-speed, and the requirement that 2*DR bracket the maximum straight distance travelled (including a $3\sigma$ sensor range error) by the target during the time to Lock-on. In this case, it seems evident that the PA might be improved by this procedural change. The shift is calculated as

$$\text{POA-shift} = Y_{max} - DR + 3*\sigma_R$$

where $\sigma_R$ is the SIGRL-value for the UAT-simulation, and the SIGRE-value for the OTH-model. If a negative value for the POA-shift is computed, then no shift will be applied. Both models compare the PA for the shifted and unshifted POA-cases. This shift of the POA assures the complete cover of the "forward" portion of the straight target-track within the time to Lock-on, and an improved partial cover even when the target makes a radical (up to 180°) course change to either side. Fig 9 depicts the construction of this shift, while Fig 10 shows the actual offset of the search pattern caused by the shift. The model shows that the potential decrease in PA is much smaller than the improvement obtained when the POA is shifted.




1-Search depth 2*DR of sector without POA-shift

2-Sector offset in DR-direction caused by $+3\sigma_R$
3-Sector offset in DR-direction caused by $-3\sigma_R$

4-Search depth 2*DR of sector with POA-shift

5-Sector offset in DR-direction caused by $+3\sigma_R$
6-Sector offset in DR-direction caused by $-3\sigma_R$

Figure 9 - CONSTRUCTION OF THE POA-SHIFT

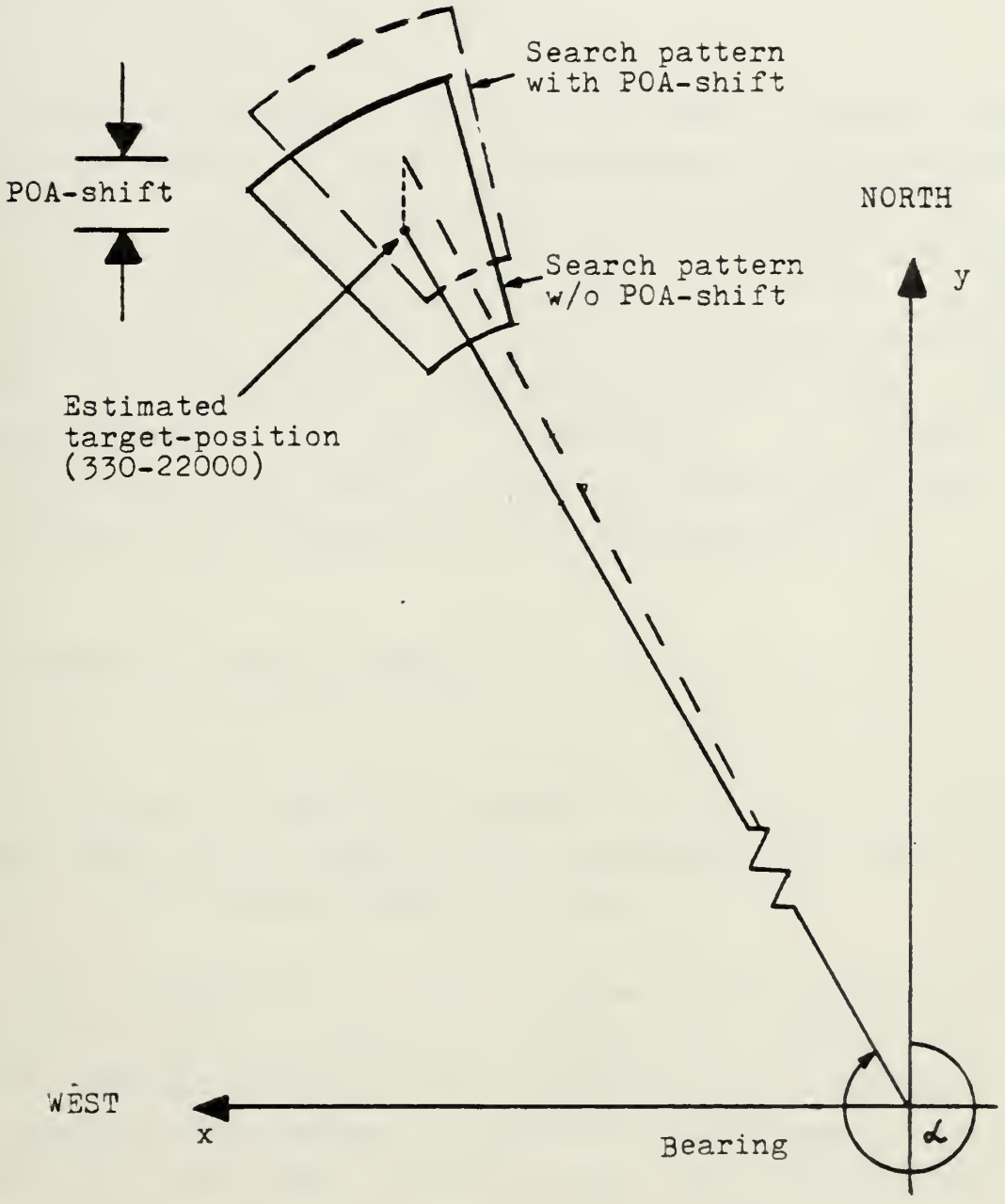



Figure 10 - RELATION OF SEARCH-PATTERN AND POA-SHIFT

## V. MEASURE OF EFFECTIVENESS/STATISTICAL REQUIREMENTS

Computer simulation becomes a legitimate research tool, when known analytical methods cannot supply a solution for a model [4]. Given the complexity of this problem and the stochastic characteristics introduced by the many potential decision points (launch-platform) and the various evasive-maneuver options (target), a stochastic simulation model is appropriate. Simulation models place three responsibilities on the investigator: a measure of effectiveness (MOE) must be defined, a sample size must be established, and the model must be validated [4].

### A. MEASURE OF EFFECTIVENESS

The missile-attack is a success if the target's actual final position is such that the missile can acquire the target in the assigned search-pattern.

This acquisition of the target is equivalent to the Lock-on; in the real world the success is defined by the radar Lock-on, whereas in the simulation world generated by the computer the success is defined by the presence of the target in the radar search area; its determination is obtained by geometrical calculations. Each run of the simulation is tested for all possible search-pattern combinations, and evaluated as a part of a binomial experiment (success or failure).

The MOE fcr each parameter combination is defined as

$$MOE = p = \frac{\#\ of\ successes}{\#\ of\ trials}$$

The second experiment calculates the same MOE for each parameter combination when the POA is shifted forward along the initial target-course.

## B. SAMPLE SIZE

Computer simulation allows multiple replication of an experiment. Independent replications mean that an experiment is rerun with selected changes in parameters, in operating conditions, or in the sequence of random numbers used to drive the model. All three are used in this simulaticn model.

To determine the sample size for replications required to estimate the true parameter p for the PA with a specified limit of error in both directions (accuracy), the following formula is applied [5]:

$$n = \frac{(z_{1-a/2})^2 * p(1-p)}{e^2}$$

A sample of size n guarantees a probability not greater than a, that the estimate of p is in error by more than e. Since the true parameter p is unknown, and no prior information about p is available, then a value of p' = 0.5 is used because it leads to a "worst case" value of n.

The formula then simplifies to

$$n = \frac{(z_{1-a/2})^2}{4\epsilon^2}$$

For the purpcse of this analysis, the confidence coefficient 1-a to be associated with the resulting estimate is chosen to be equal to 0.95, that means a=0.05 and a/2=0.025; the related two-sided value $z_{0.975}$ of the standard normal variable is 1.960; the error e permitted in the estimate was set at 0.05. The sample size was then fixed at 400. This value is used for the number of replications in both simulation models.

## C. VALIDATION

The computer model output was compared with ship performance data (FGN-DDG, Hamburg-Class), and with actual flight-test data obtained from the manufacturer and the FGN. These references are included in the classified Appendix. Validation is discussed further at that point.

# VI. UNASSISTED TARGETING-SCHEME

The simulation model MM38-UAT is used to model engagements in which the attack range is within the FPBG radar-horizon and no target information is available from an extended platform. Use of intermittent radiation of the relevant surface search radar provides information about target-position and target-motion, and by the use of ESM, visual means and/or intelligence reports, a target classification is possible.

## A. TARGETING GEOMETRY

The simulation comprises the time development from the initiation of the missile launch - "press the button" - until the expected Lock-on time. This assumes that the target is already in the launch-sector, and the missile gyros are stabilized.The delaytimes were discussed in section III.C.2. In Fig 11 and 12, the actual position at Lock-on-time is shown, and all sources of errors have been considered. Fig 11 depicts the targeting geometry without a shift of the POA; whereas Fig 12 shows the gecmetry including this shift.

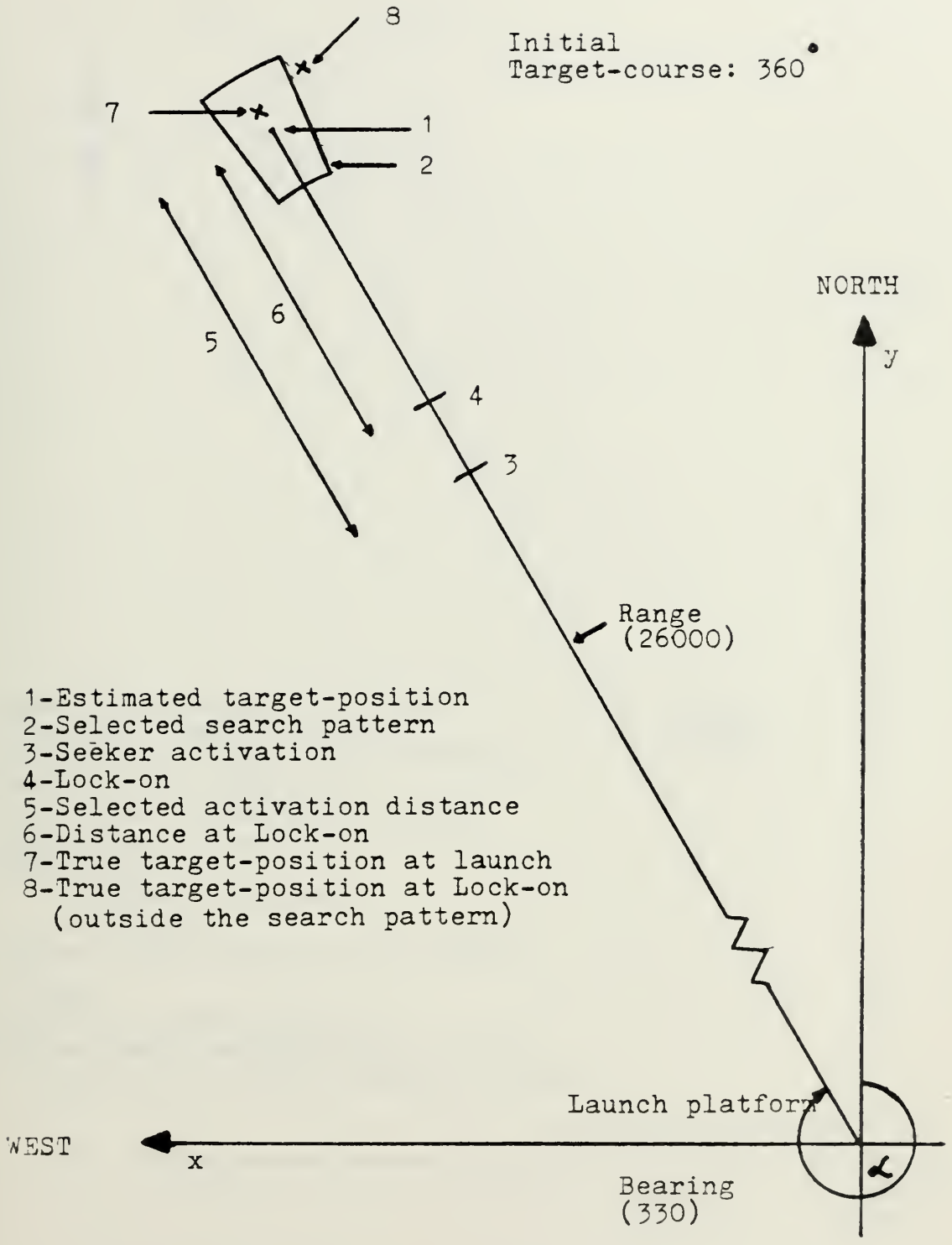



Figure 11 - TARGETING GEOMETRY FOR MODEL MM38-UAT
(WITHOUT POA-SHIFT)

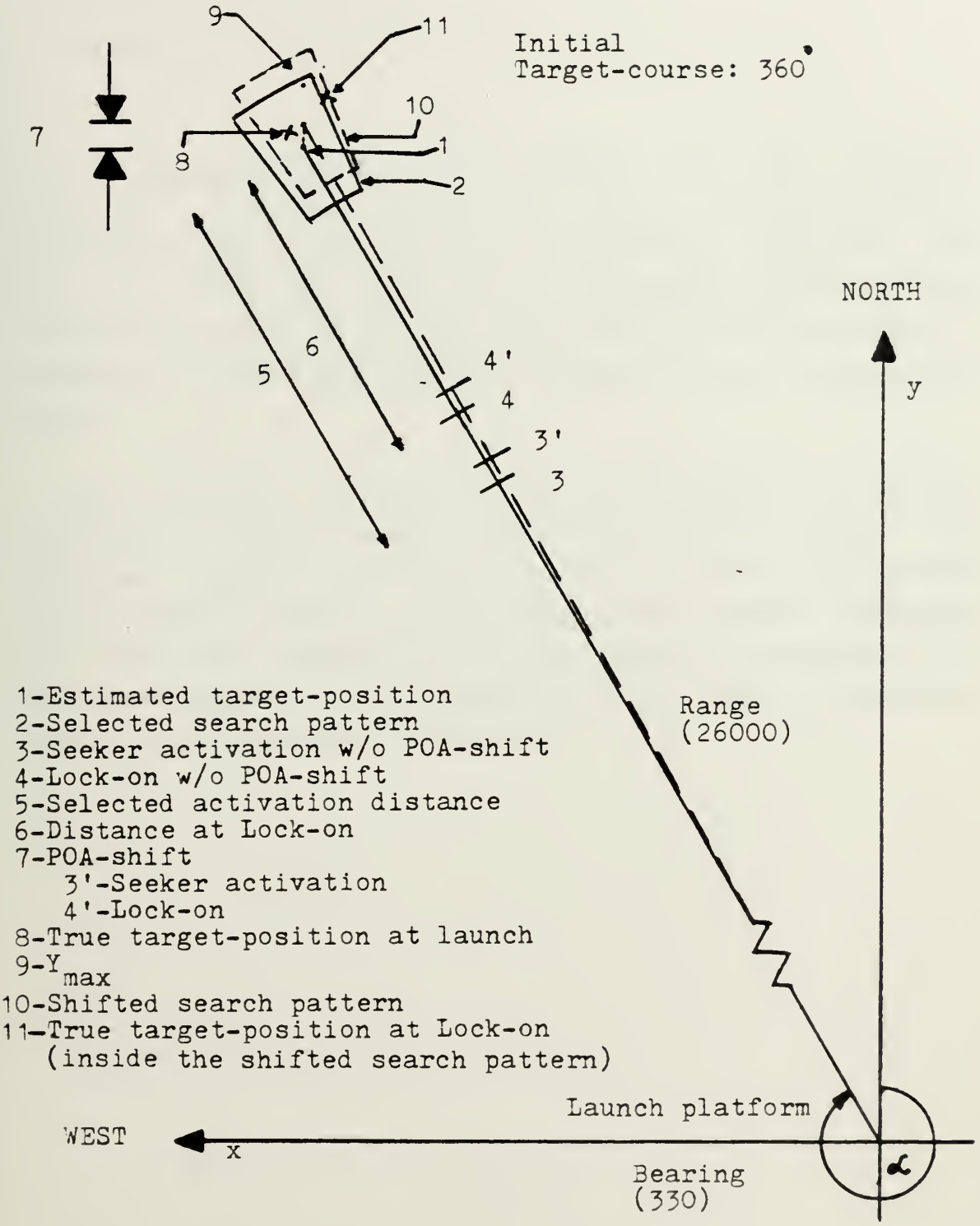



Figure 12 - TARGETING GEOMETRY FOR MODEL MM38-UAT
(WITH POA-SHIFT)

## B. RESULTS

An analysis of variance (ANOVA) for all involved variables of the simulation model was performed to investigate their influence on the dependent variable, the PA. It turned out that all independent variables have significant effect on the PA, and also it is not possible to establish a linear relationship between any one variable and the PA.

The following tables and figures present the MOE as a function of target aspect-angle and target range. The indicated ranges are the upper bound limits to which the missile can be launched with the specified search pattern, and obtain the required PA of 0.99. Due to the symmetry of the aspect-angles only the positive angle-data (target-bow points to the right) are presented.

1. PA w/r to Wind Effects

The component of the wind in the direction of the missile's trajectory does not significantly affect - less than 3% - the PA for all target types, parameter combinations, target ranges, and aspect-angles.

2. PA w/r to Target Range

Tables III to VI refer to the four different target types and the ranges from 14000 m to the respective RP1-range. When the equivalent RP1-range is given as an entry in the table, in most of the cases this is an indication that a PA of at least 0.99 is also given beyond the specified range. The first value (1) is calculated without the POA-shift, the second value (2) takes this shift into account. Otherwise, the tables are self-explanatory.

Not surprisingly, the results support the hypothesis that the PA can be improved by reducing the missile launching distance, the range to the target. For all parameter combinations, decreasing the target range can increase the PA to 1.0. This is valid for all target types, but at different ranges and with different search patterns. Table VII for the high initial speed case of the DDG target shows the same tendency.

| PATTERN / ANGLE | KKK | KKG | KGK | KGG | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|---|---|
| 0 (1) | 22000 | 23000 | 22000 | 28000 | 30000 | 32000 | 31000 | 32000 |
| 0 (2) | 22000 | 23000 | 26000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 30 | 20000 | 21000 | 22000 | 28000 | 30000 | 32000 | 31000 | 32000 |
| | 20000 | 21000 | 26000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 60 | 18000 | 18000 | 25000 | 27000 | 32000 | 32000 | 32000 | 32000 |
| | 18000 | 18000 | 28000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 90 | 17000 | 17000 | 26000 | 26000 | 32000 | 32000 | 32000 | 32000 |
| | 17000 | 17000 | 28000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 120 | 19000 | 19000 | 27000 | 28000 | 32000 | 32000 | 32000 | 32000 |
| | 19000 | 19000 | 32000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 150 | 22000 | 22000 | 28000 | 29000 | 32000 | 32000 | 32000 | 32000 |
| | 22000 | 22000 | 32000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 180 | 25000 | 25000 | 30000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| | 25000 | 25000 | 32000 | 32000 | 32000 | 32000 | 32000 | 32000 |

RF1: 32000 M

Table III - RELATION SEARCH PATTERN/ASPECT-ANGLE
MAXIMUM TARGET RANGE FOR PA=0•99
DDG KRIVAK-CLASS (LOW SPEED)

| PATTERN / ANGLE | KKK | KKG | KGK | KGG | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|---|---|
| 0 (1) | 21000 | 23000 | 20000 | 25000 | 27000 | 29000 | 26000 | 29000 |
| 0 (2) | 21000 | 23000 | 20000 | 25000 | 29000 | 29000 | 29000 | 29000 |
| 30 | 19000 | 19000 | 20000 | 28000 | 27000 | 29000 | 27000 | 29000 |
| | 19000 | 19000 | 20000 | 25000 | 29000 | 29000 | 29000 | 29000 |
| 60 | 17000 | 17000 | 24000 | 27000 | 29000 | 29000 | 29000 | 29000 |
| | 17000 | 17000 | 29000 | 29000 | 25000 | 29000 | 29000 | 29000 |
| 90 | 16000 | 16000 | 26000 | 26000 | 29000 | 29000 | 29000 | 29000 |
| | 16000 | 16000 | 29000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| 120 | 18000 | 18000 | 27000 | 27000 | 29000 | 29000 | 29000 | 29000 |
| | 18000 | 18000 | 29000 | 29000 | 25000 | 29000 | 25000 | 29000 |
| 150 | 22000 | 22000 | 28000 | 29000 | 25000 | 29000 | 29000 | 29000 |
| | 22000 | 22000 | 29000 | 25000 | 29000 | 29000 | 29000 | 29000 |
| 180 | 25000 | 25000 | 29000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| | 25000 | 25000 | 29000 | 29000 | 29000 | 29000 | 29000 | 29000 |

RF1: 29000 M

Table IV - RELATION SEARCH PATTERN/ASPECT-ANGLE

MAXIMUM TARGET RANGE FOR PA=0•99

PFG NANUCHKA-CLASS

| PATTERN / ANGLE | KKK | KKG | KGK | KGG | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|---|---|
| 0 (1) | 21000 | 21000 | 22000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| 0 (2) | 21000 | 21000 | 26000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| 30 | 18000 | 18000 | 22000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| | 18000 | 18000 | 26000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| 60 | 16000 | 16000 | 24000 | 24000 | 26000 | 26000 | 26000 | 26000 |
| | 16000 | 16000 | 26000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| 90 | 17000 | 17000 | 24000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| | 17000 | 17000 | 26000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| 120 | 17000 | 17000 | 24000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| | 17000 | 17000 | 26000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| 150 | 20000 | 20000 | 22000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| | 20000 | 20000 | 26000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| 180 | 22000 | 22000 | 22000 | 26000 | 26000 | 26000 | 26000 | 26000 |
| | 22000 | 22000 | 26000 | 26000 | 26000 | 26000 | 26000 | 26000 |

RF1: 26000 M

Table V - RELATION SEARCH PATTERN/ASPECT-ANGLE
MAXIMUM TARGET RANGE FOR PA=0•99
FPBG OSA-CLASS

| FATTERN / ANGLE | KKK | KKG | KGK | KGG | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|---|---|
| 0 (1) | 27000 | 29000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| 0 (2) | 27000 | 29000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| 30 | 24000 | 25000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| | 24000 | 25000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| 60 | 21000 | 21000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| | 21000 | 21000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| 90 | 20000 | 20000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| | 20000 | 20000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| 120 | 22000 | 22000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| | 22000 | 22000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| 150 | 27000 | 27000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| | 27000 | 27000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| 180 | 29000 | 29000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |
| | 29000 | 29000 | 27000 | 29000 | 29000 | 29000 | 29000 | 29000 |

RF1: 29000 M

Table VI - RELATION SEARCH PATTERN/ASPECT-ANGLE
MAXIMUM TARGET RANGE FOR PA=0•99
LSM POLNOCNY-CLASS

| PATTERN / ANGLE | KKK | KKG | KGK | KGG | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|---|---|
| C (1) | 15000 | 20000 | 15000 | 25000 | 22000 | 32000 | 21000 | 32000 |
| C (2) | 15000 | 20000 | 15000 | 28000 | 32000 | 32000 | 21000 | 32000 |
| 30 | 15000 | 16000 | 16000 | 23000 | 22000 | 32000 | 23000 | 32000 |
| | 16000 | 16000 | 16000 | 30000 | 32000 | 32000 | 32000 | 32000 |
| 60 | - | - | 20000 | 21000 | 26000 | 30000 | 25000 | 32000 |
| | - | - | 23000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 90 | - | - | 21000 | 21000 | 30000 | 30000 | 32000 | 32000 |
| | - | - | 26000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 120 | 14000 | 14000 | 23000 | 23000 | 32000 | 32000 | 32000 | 32000 |
| | 14000 | 14000 | 28000 | 32000 | 32000 | 32000 | 32000 | 32000 |
| 150 | 18000 | 18000 | 22000 | 26000 | 28000 | 32000 | 28000 | 32000 |
| | 19000 | 19000 | 28000 | 28000 | 32000 | 32000 | 32000 | 32000 |
| 180 | 21000 | 23000 | 21000 | 32000 | 28000 | 32000 | 28000 | 32000 |
| | 22000 | 22000 | 30000 | 30000 | 32000 | 32000 | 32000 | 32000 |

RF1: 32000 M

Table VII - RELATION SEARCH PATTERN/ASPECT-ANGLE
MAXIMUM TARGET RANGE FOR PA=0•99
DDG KRIVAK-CLASS (HIGH SPEED)

### 3. PA w/r to Target Aspect-Angle

Fig 13 to 21 describe the PA as a function of the various aspect-angles and the three ranges RP9, RP5, and RP1, which are defined for each target type in Appendix B. The graphs depict this relation for only two target types, the DDG and the LSM, as significant proxies for a rapidly and a slowly reacting ship. The variant of the high initial speed for the DDG target is also analyzed.

Almost the same tendency can be observed in the various PA-curves over the whole aspect-angle set for the other two target types. The parameter combinations KKK and KKG are the most sensitive to a change of the aspect-angle for the target types DDG, PFG and FPBG, at their respective RP9-range. The PA-values decrease from a maximum of 1.0 at the aspect-angle 0° to their respective minima 0.88,0.83,0.83) at the aspect-angle 90° and then follow an increasing trend back to the maximum value of 1.0 at 180°.

The PA-curves in the LSM family are similar, but differ from the curves in the DDG, PFG, and FPBG family. They also show a minimum for all search patterns at 90°. For the search patterns KKK and KKG the high initial speed case for the DDG generates PA-curves which are very distinct from the curves generated by the low initial speed case. The PA-values at aspect-angle 0° are 0.66 and 0.95 respectively, they both decrease to a minimum value of 0.09 at aspect-angle 90°, and reach their maximum value of 0.99 and 1.00 at 180°. The curve for the search pattern KGK has a very different shape; at aspect-angle 0° it has its minimum of 0.64. The PA increases with the aspect-angle to 60° (0.94); then it follows the same trend of the other patterns, namely PA-values between 0.95 and 1.0.

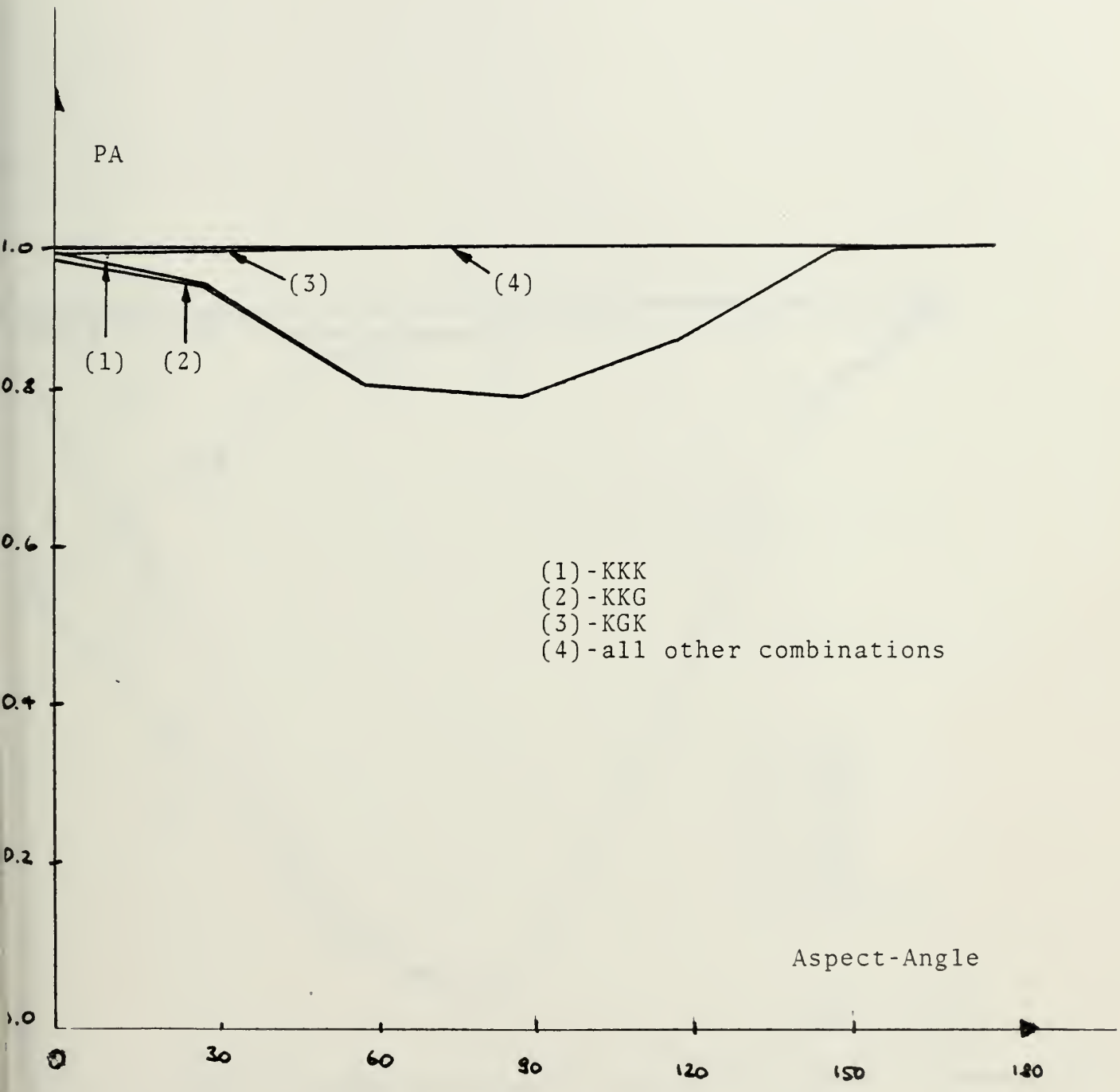



Figure 13 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
DDG TARGET (LOW SPEED) - RP9 -

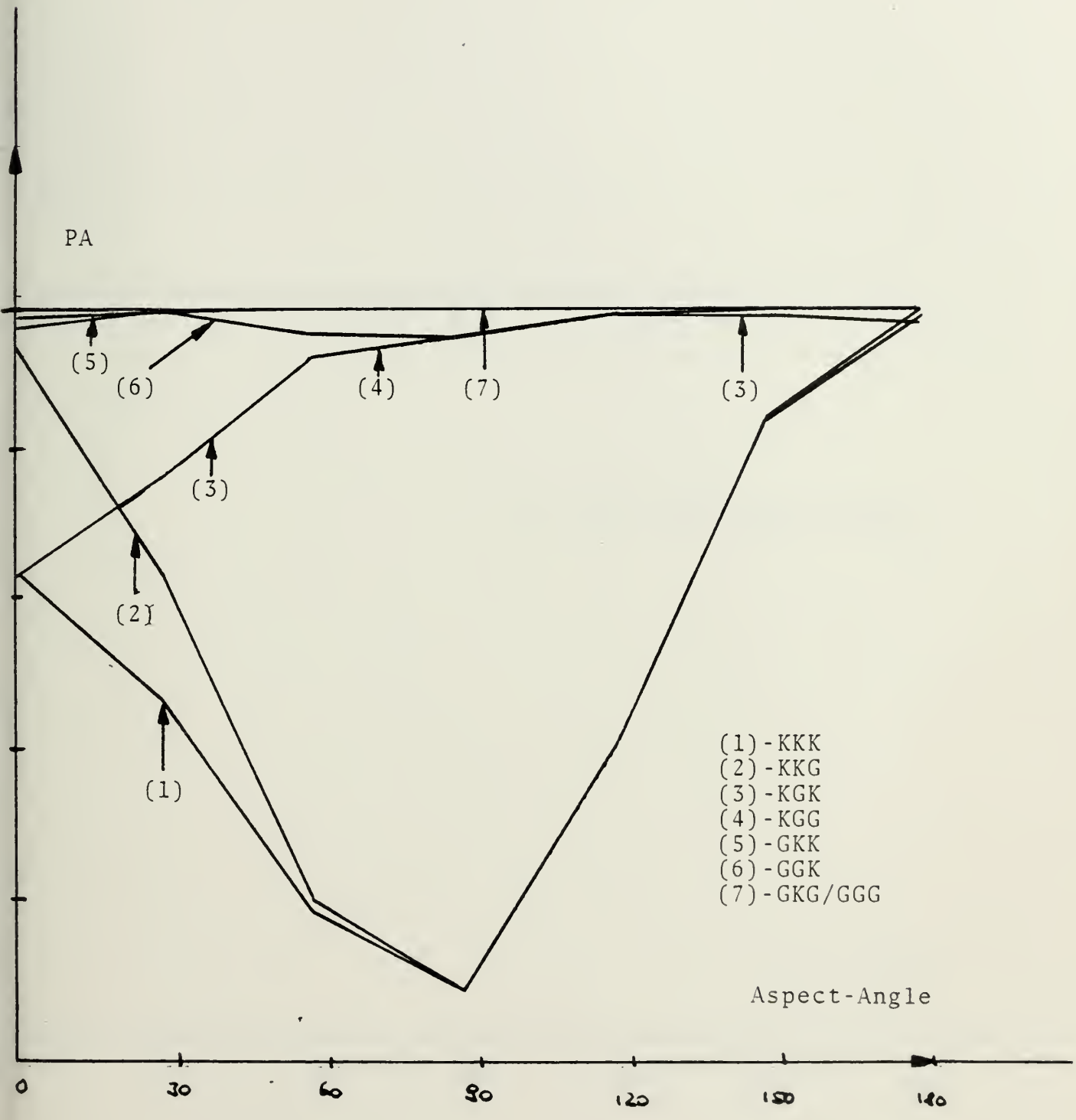



Figure 14 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
DDG TARGET (HIGH SPEED) - RP9 -

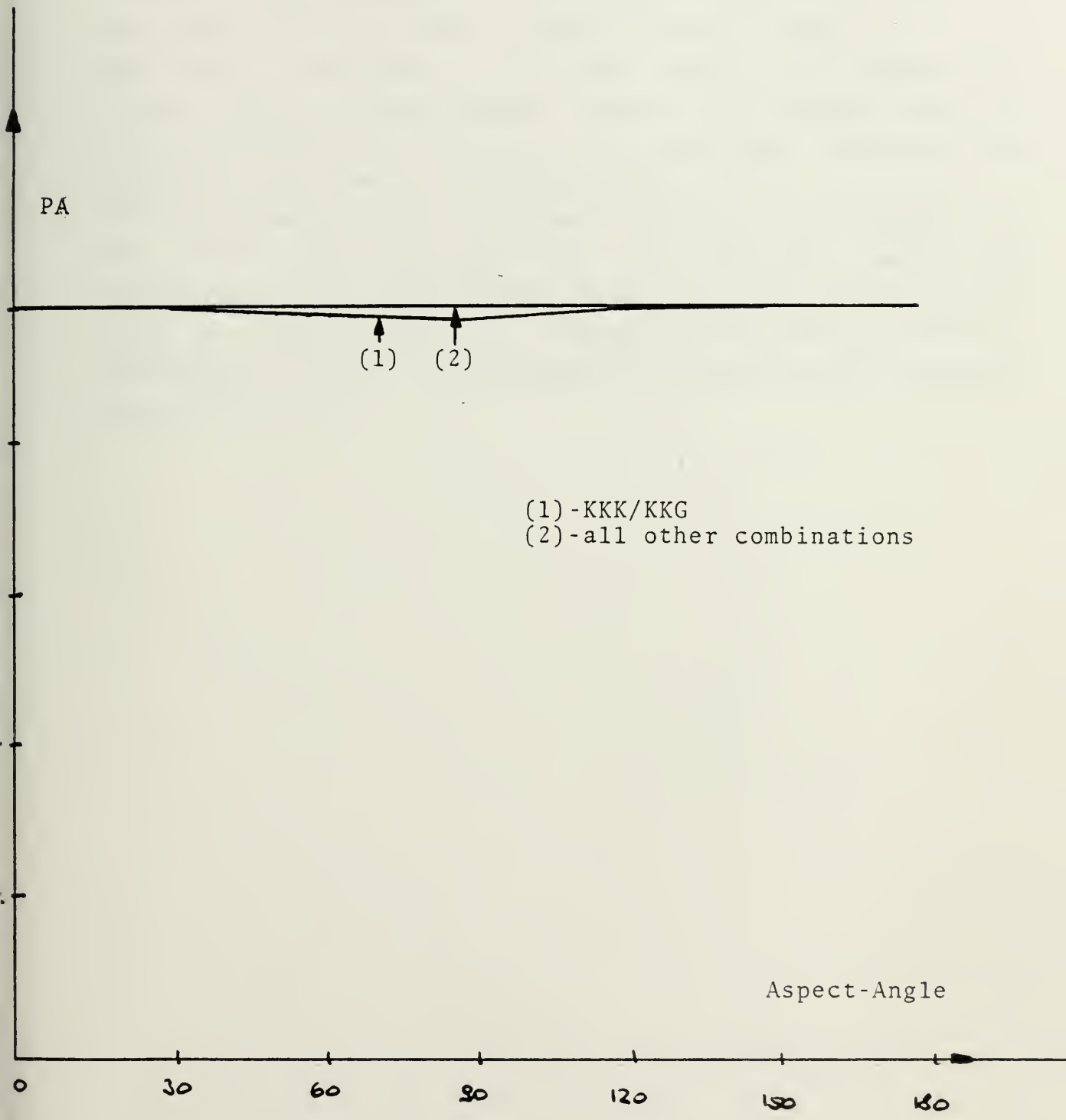



Figure 15 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
LSM TARGET - RP9 -

For the RP5-range the same PA-curve characteristic holds for all parameter combinations. The patterns KKK and KKG have an increased absolute slope, compared to the RP9-range. The curves for the LSM target are similar to those of the other target types at this range. The KGK curves decrease more sharply, but generally approach the limiting 1.0 value at an aspect-angle of 90°.

The PA-curves for the high speed DDG target correspond to the same three patterns for the RP9-range, with the distinction, that the maximum values at aspect-angles 0° and 180° are less than 1.0, and the minimum value at 90° is decreased by 0.02. the patterns GKG and GGG do not deviate frcm 0.99 or 1.0.

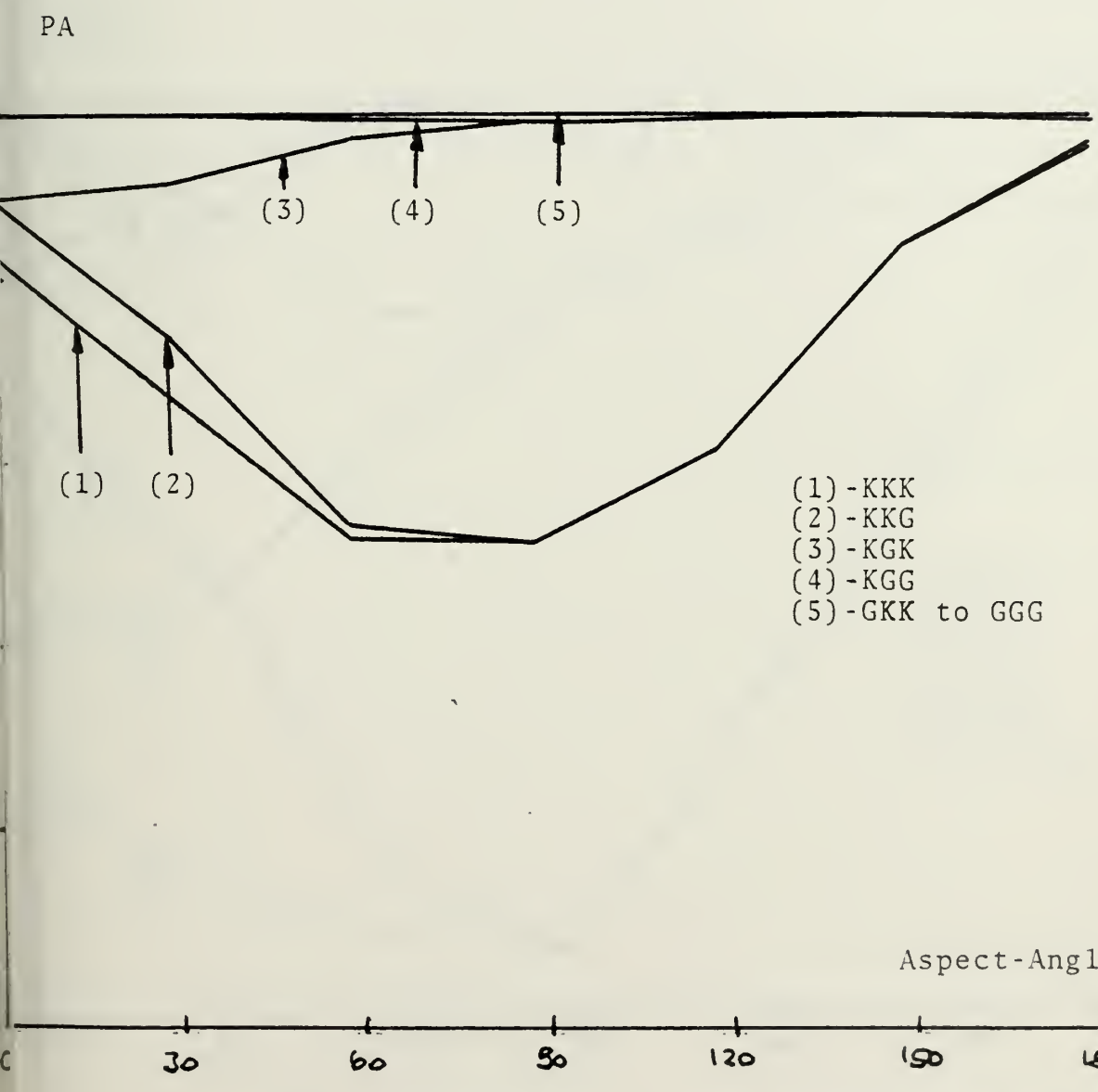



Figure 16 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
DDG TARGET (LOW SPEED) - RP5 -

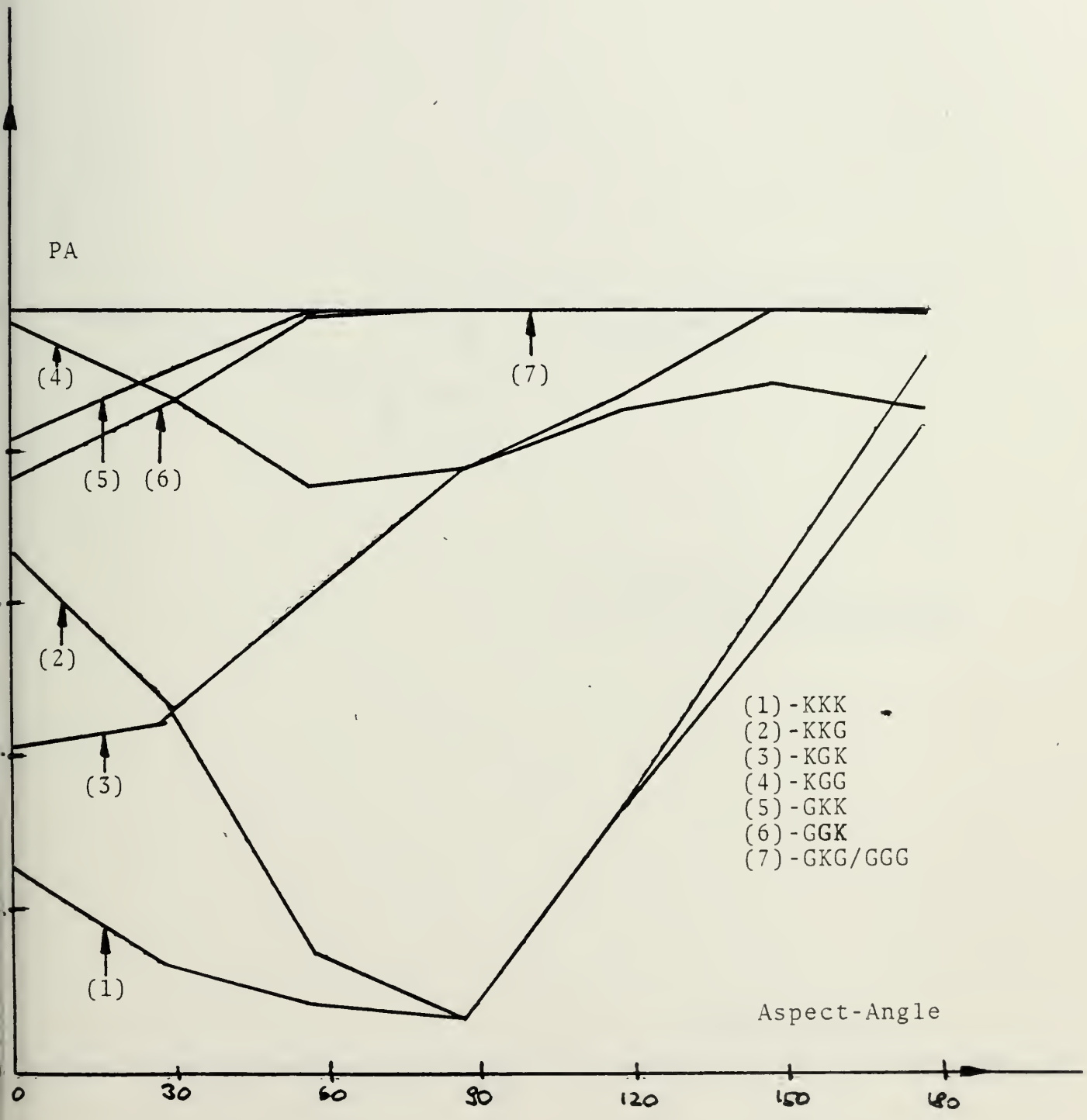



Figure 17 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
DDG TARGET (HIGH SPEED) - RP5 -

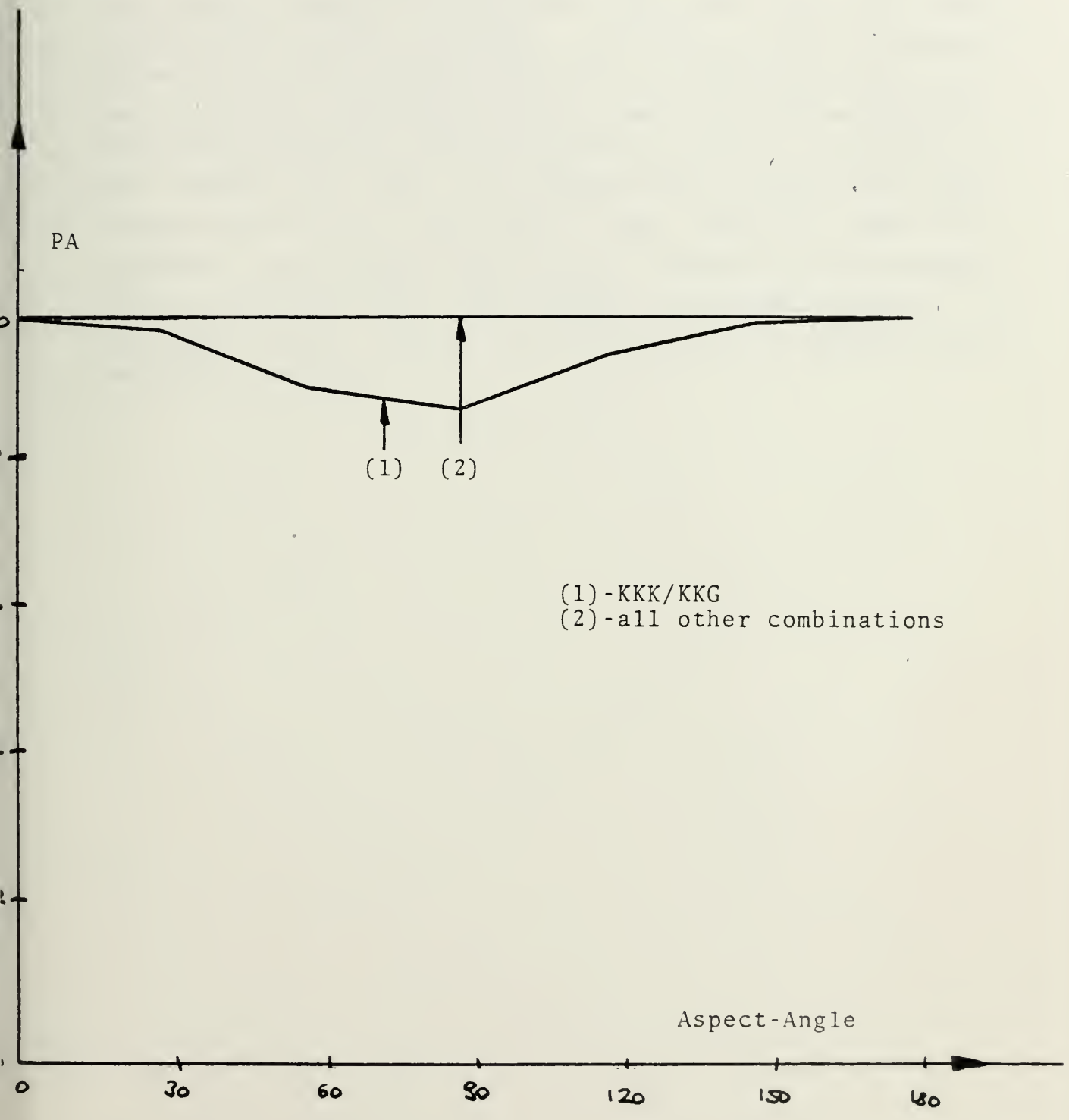



Figure 18 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
LSM TARGET - RP5 -

For the RP1-range the PA-curves for the target types PFG, FPEG, and LSM follow the same general behavior as for the previcus ranges RP9 and RP5. The graph for the high acceleration DDG, however, reveals a very distinct dependence on the aspect-angle and a different shape for each parameter combination at the small activation-distance. The minimum PA-value varies from 30° to 90° but returns to the maximum at 180°. The patterns GKK and GGK have their minimum value at 0° (0.92,0.89) with positive slope and approach the limiting value of 1.0 reached by the patterns GKG and GGG at 90°. The slopes increased further in absolute values. Almost the same trend can be observed for the high speed DDG.

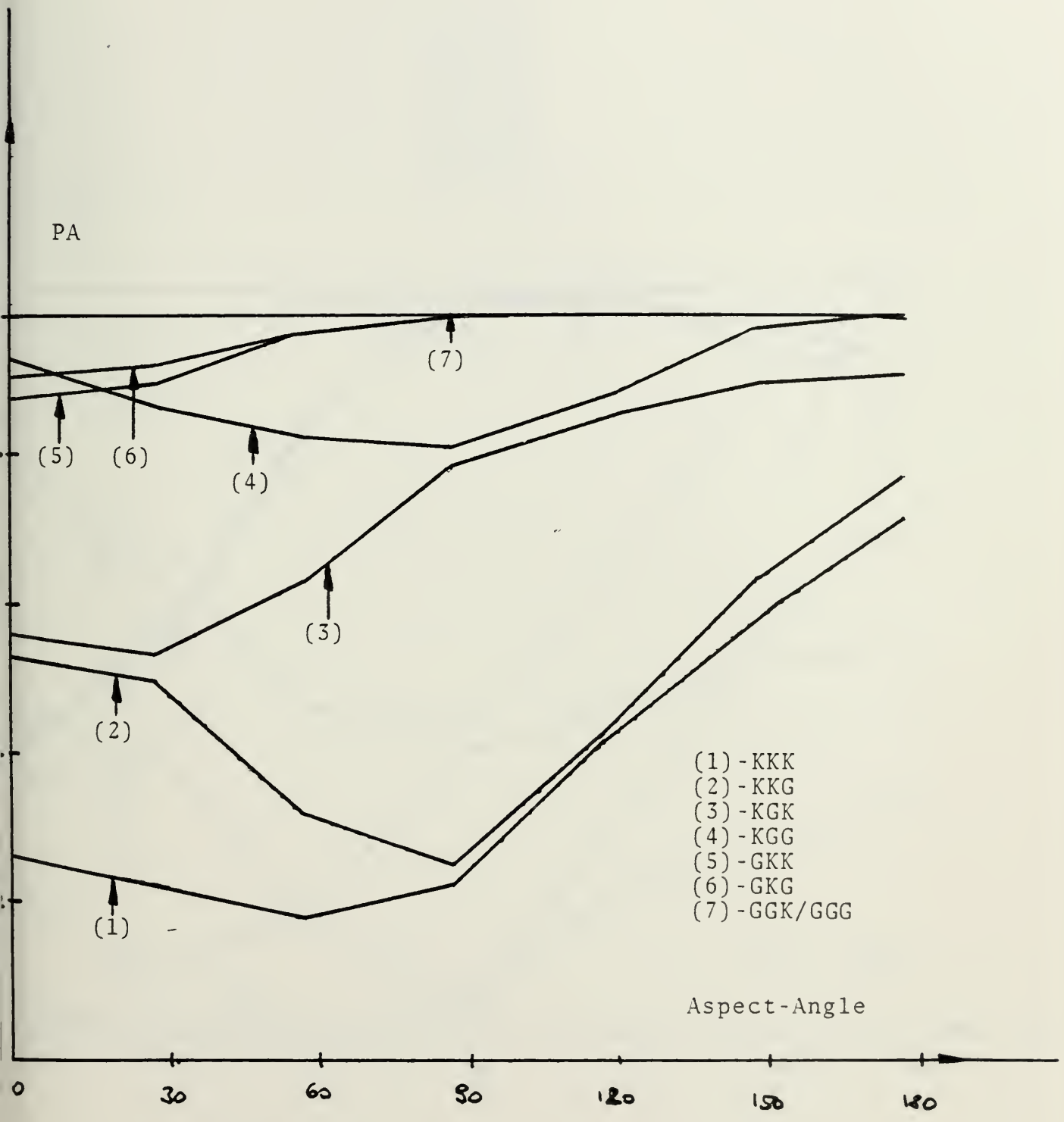



Figure 19 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
DDG TARGET (LOW SPEED) - RP1 -

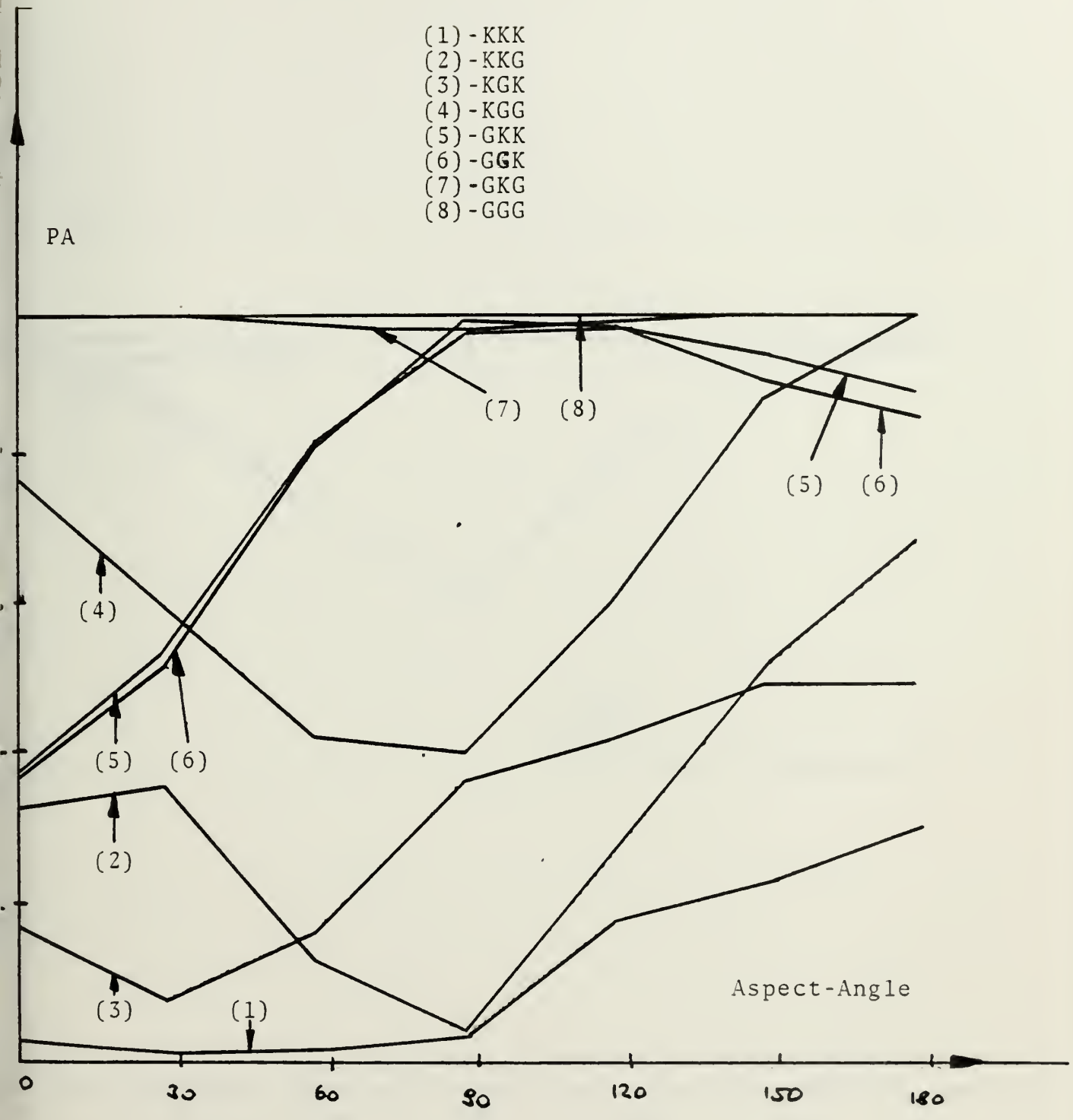



Figure 20 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
DDG TARGET (HIGH SPEED) - RP1 -

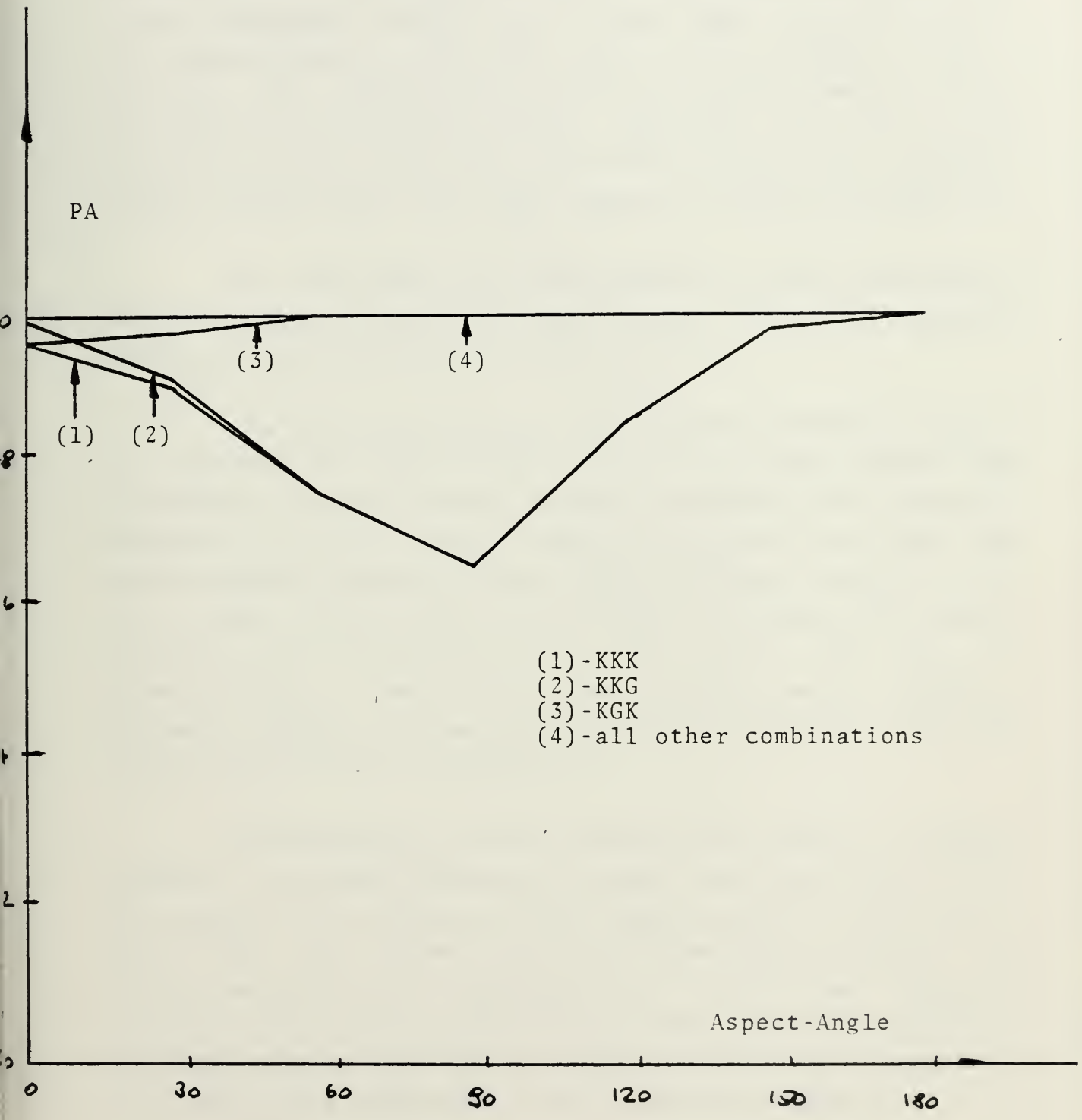



Figure 21 - RELATION PA - TARGET ASPECT-ANGLE W/O POA-SHIFT
LSM TARGET - RP1 -

The inclusion of the POA-shift for the LSM target produces no change in the behavior of the PA-curves over all three RP-ranges, because the the magnitude of the POA-shift is insignificant. For the other three target types, however, the graphs reveal similar behavior over all three RP-ranges; the PA-curves for the RP9-range show the same trend as for the LSM target; the POA-shift for this range is almost neglible for all target types, see Fig 22 and Fig 23.

The RP5-range with the related POA-shift produces a flatter PA-curve for all aspect-angles with the minimum still at 90°, see Fig 24 and Fig 25.

The RP1-range PA-curves for the PFG and FPBG targets are similar to each other, and to the curves without the POA-shift. The DDG target, however, generates very distinct PA-curves for the search pattern KKK and KKG, which now their maximum between 60° and 120°, and their minimum at 0° and 180°. The other four search pattern are almost identical with a PA-value of not less than 0.98 for all aspect-angles, see Fig 19 and 26.Even more distinct, although similar, is the trend of the PA-curves for the high speed DDG, see Fig 20 and Fig 27.

Interpretation of the graphs shows that the results support the second hypothesis, which states that the PA can be improved by a properly chosen aspect-angle to the target. Note that this is not the radar cross section effect. It occurs because of the dependence of PA on the target's mobility. The convolution of this effect with the variation in cross section with aspect-angle has not been explored. This problem is addressed in the classified appendix.

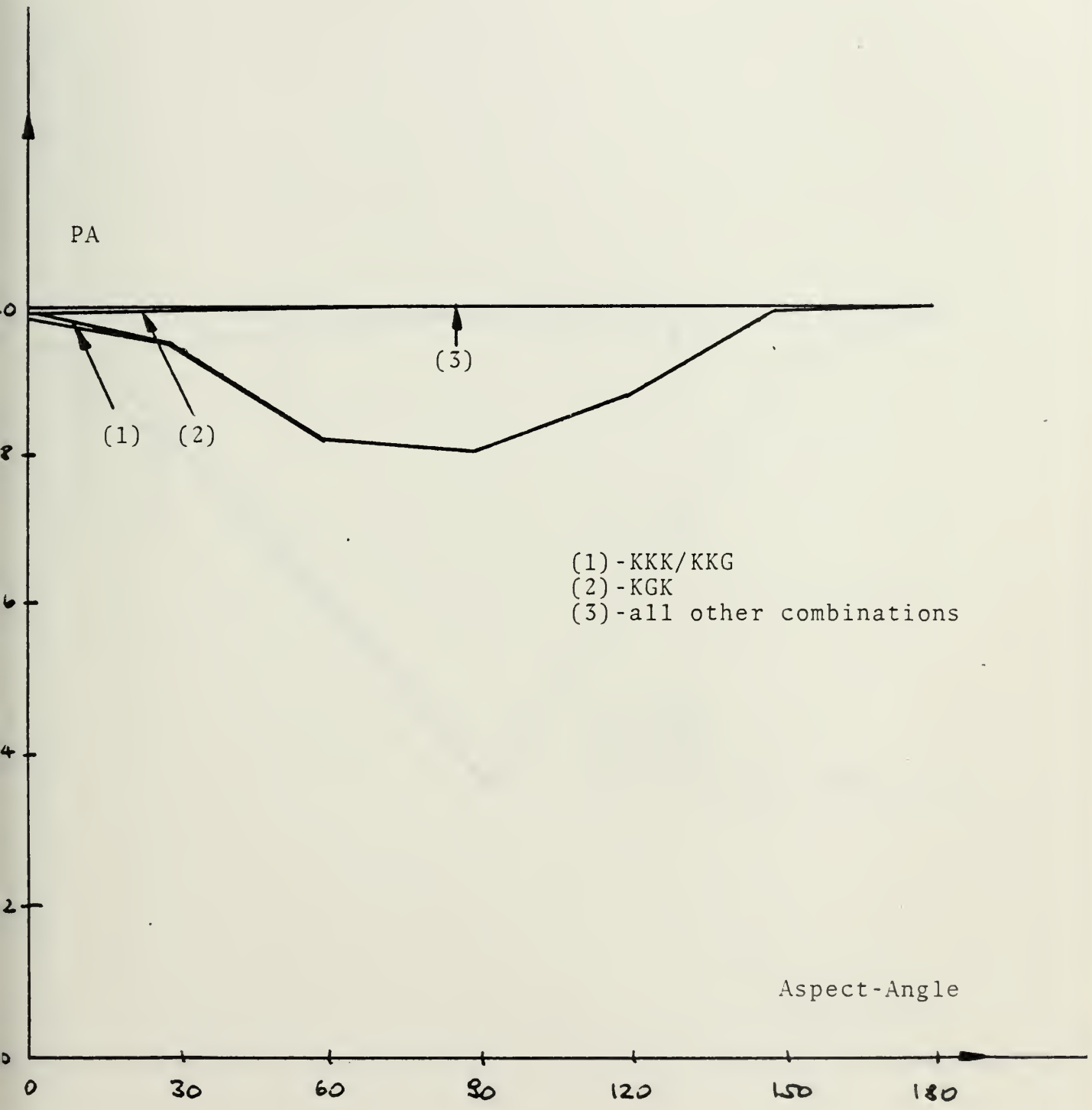



Figure 22 - RELATION PA - TARGET ASPECT-ANGLE W POA-SHIFT
DDG TARGET (LOW SPEED) - RP9 -

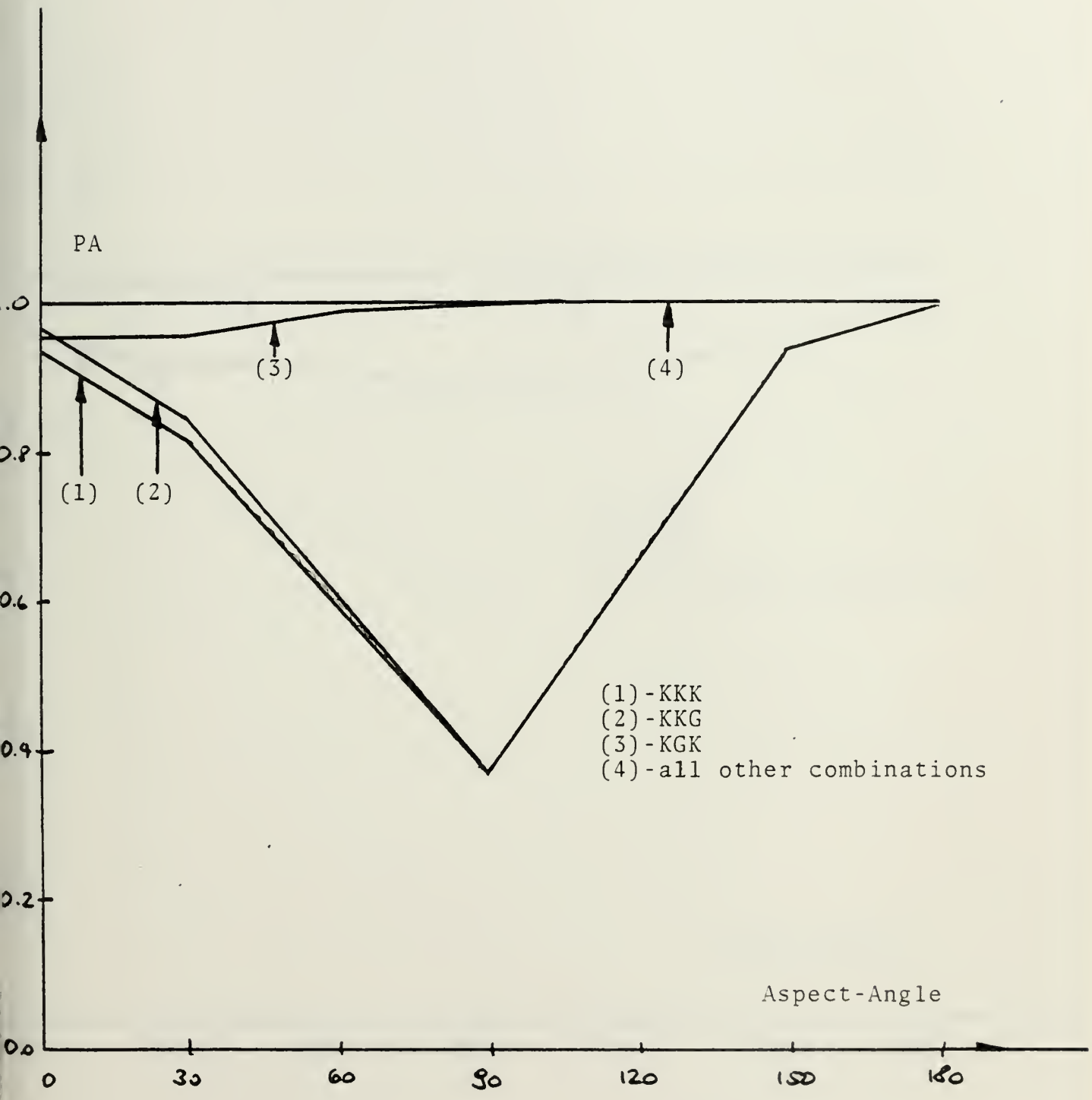



Figure 23 - RELATION PA - TARGET ASPECT-ANGLE W POA-SHIFT
DDG TARGET (HIGH SPEED) - RP9 -

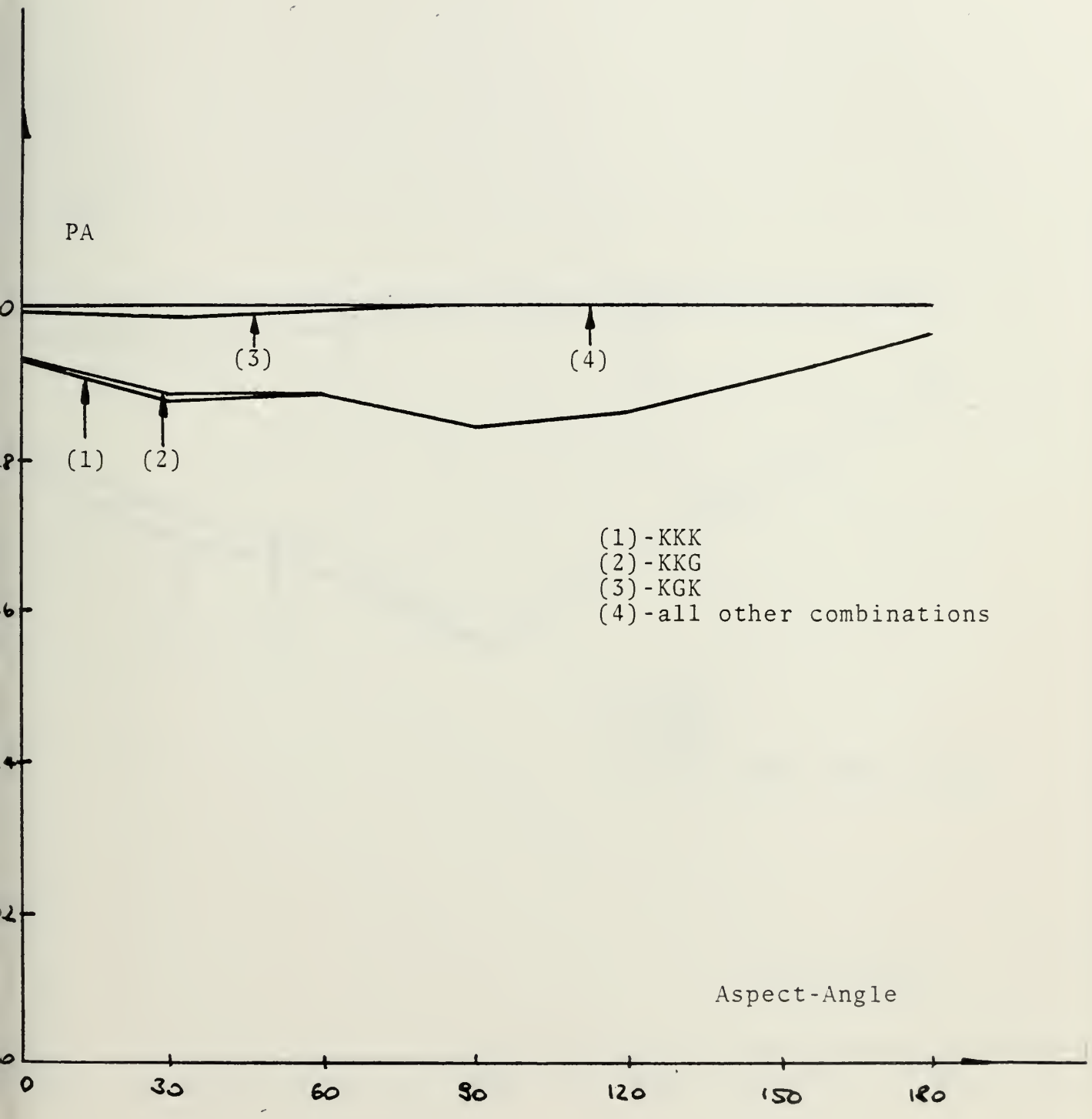



Figure 24 - RELATION PA - TARGET ASPECT-ANGLE W POA-SHIFT
DDG TARGET (LOW SPEED) - RP5 -

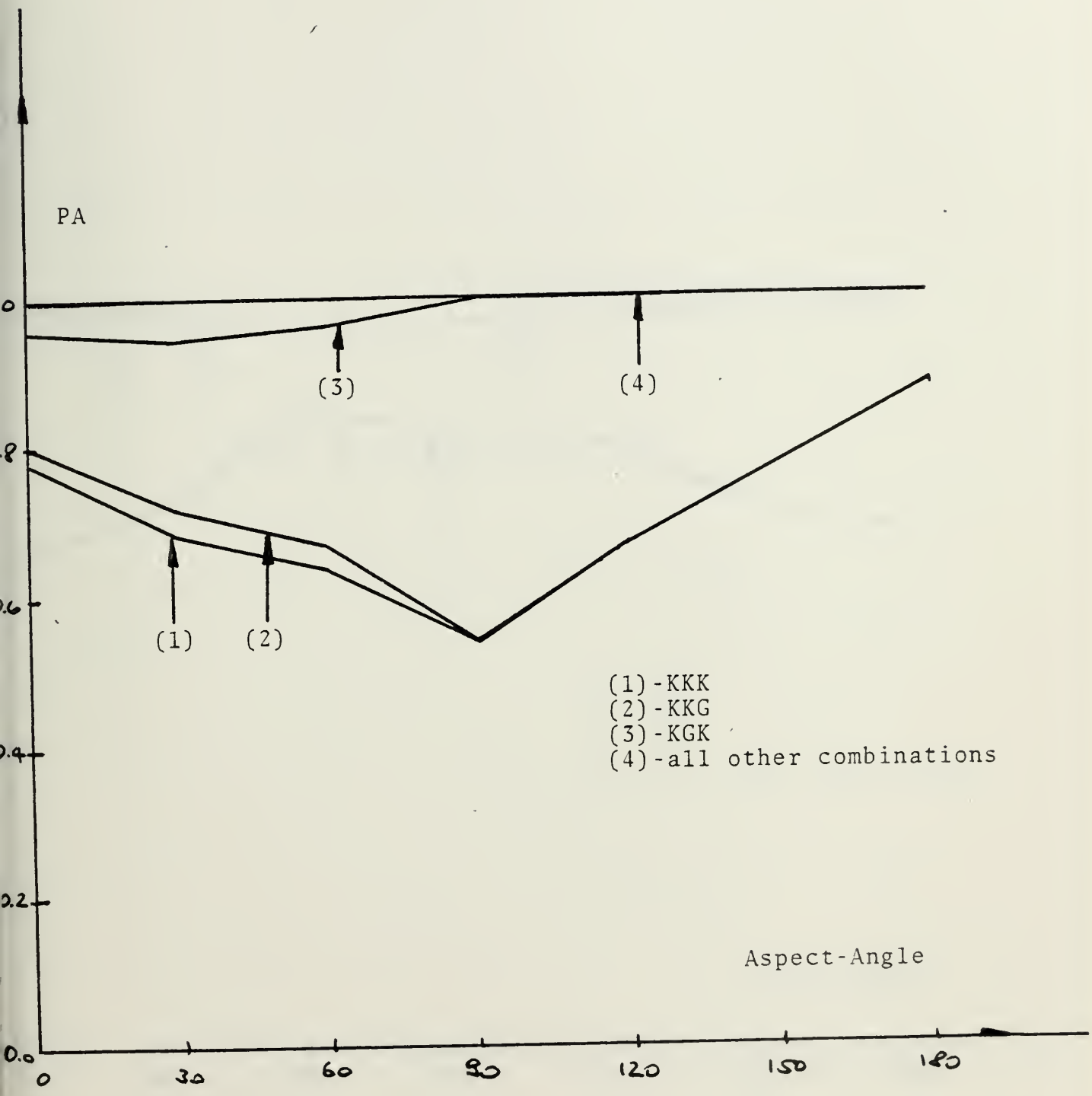



Figure 25 - RELATION PA - TARGET ASPECT-ANGLE W POA-SHIFT
DDG TARGET (HIGH SPEED) - RP5 -

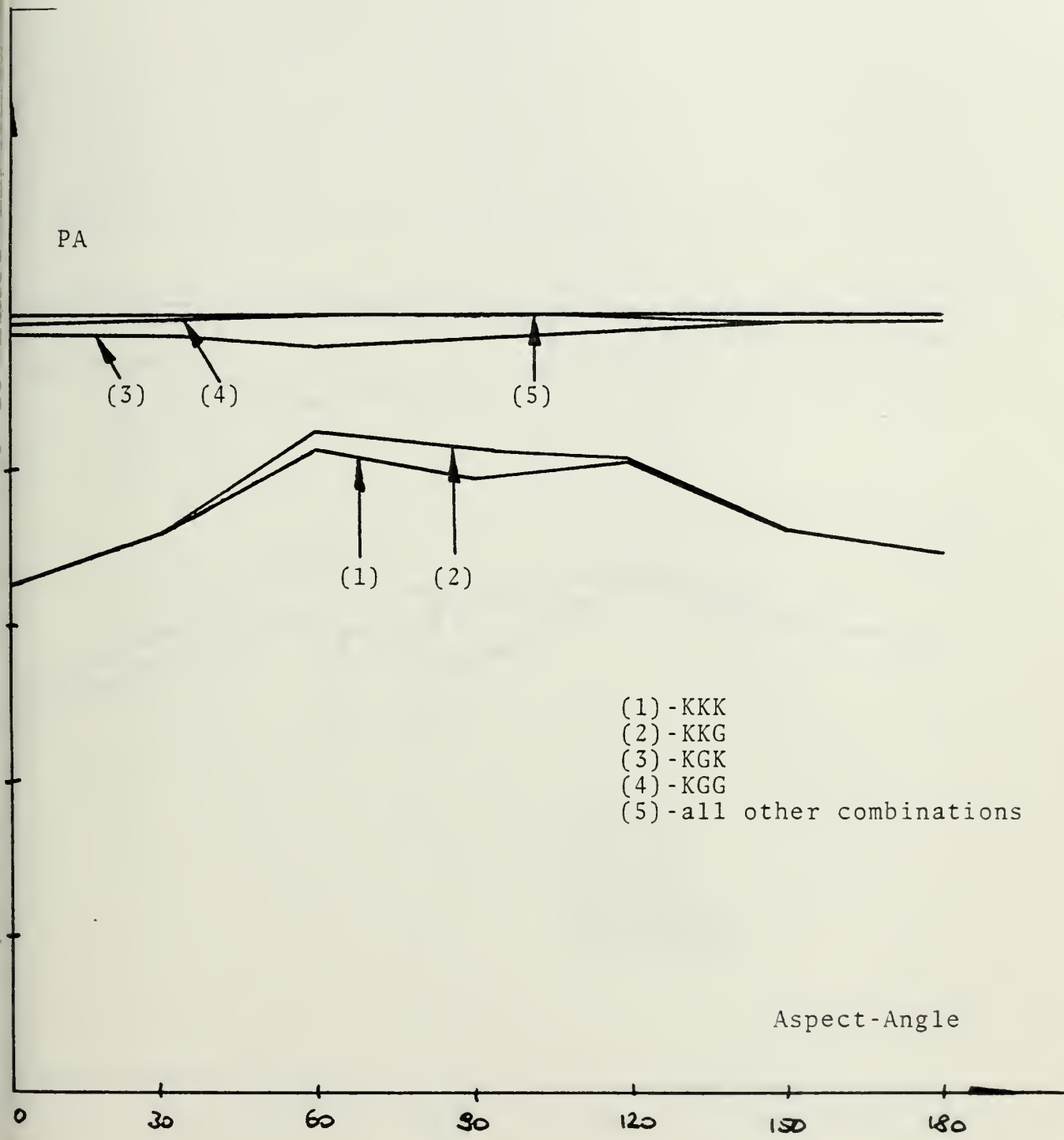



Figure 26 - RELATION PA - TARGET ASPECT-ANGLE W POA-SHIFT
DDG TARGET (LOW SPEED) - RP1 -

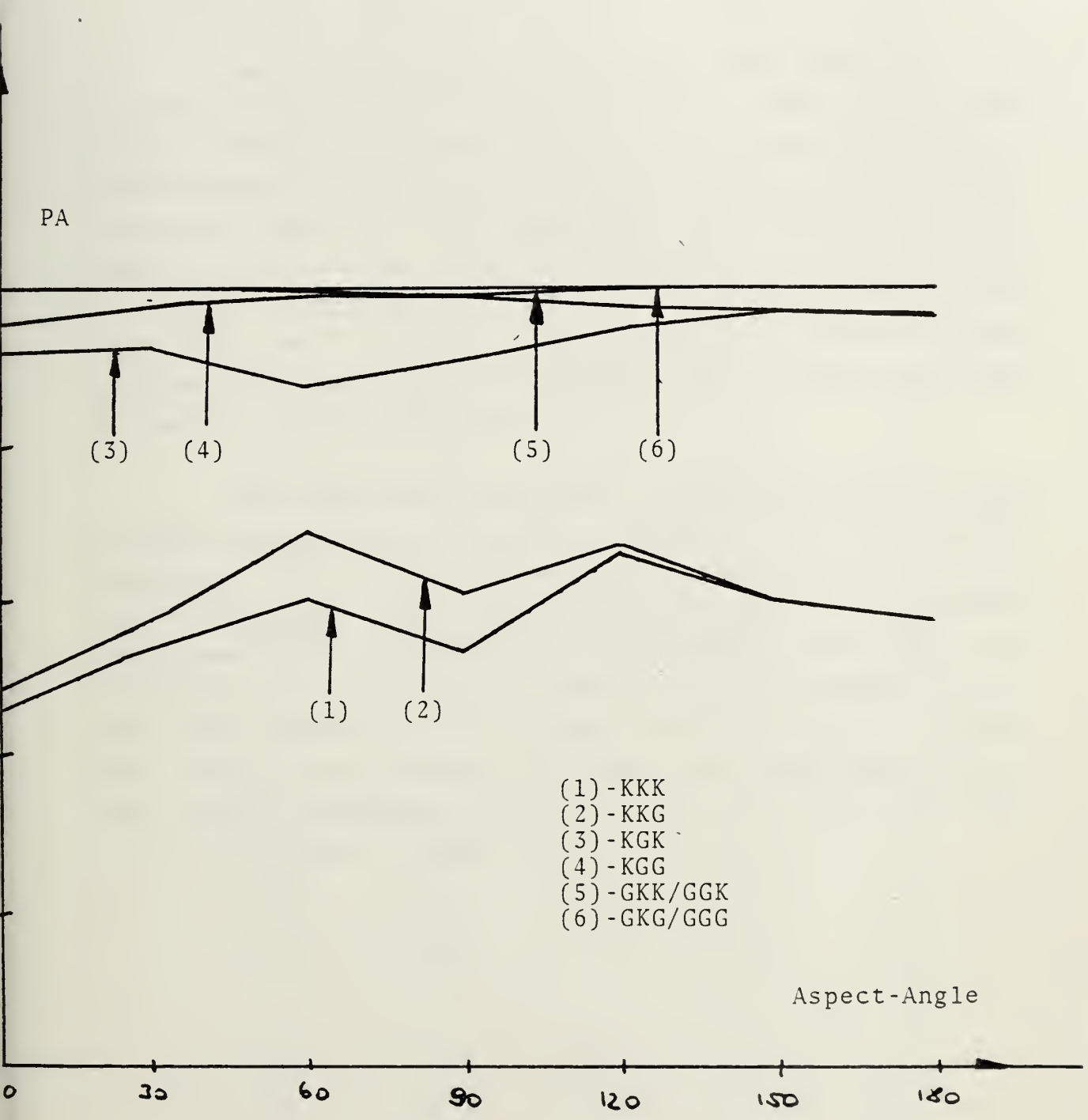



Figure 27 - RELATION PA - TARGET ASPECT-ANGLE W POA-SHIFT
DDG TARGET (HIGH SPEED) - RP1 -

### 4. PA w/r to POA-Shift

The previous two subsections, which dealt with the interdependence of PA and target range as well as PA and target aspect-angle, reveal that an intentional POA-shift in the direction of the projected target-motion significantly increased the PA. The only exception was the LSM, the slowly reacting ship, where the POA-shift did not affect the PA. These results support the third hypothesis. The fourth hypothesis, which stated, that the PA can be improved by any combination of an appropriate target range, aspect-angle and POA-shift, is also verified.

The additional experiment for the DDG target, where a high initial speed is assumed, revealed its significant influence on the PA for all search patterns at the three range variants, and therefore emphasized the potential importance of the POA-shift. It turned out that with this POA-shift the search patterns GKK and GGK in addition to GKG and GGG assure a PA of at least 0.99 over the whole range set, which is not the case without the implementation of this shift. Excerpts of the PA-results for an aspect-angle of 30° are shown in Table VIII.

1. 14-30 KTS NO POA-SHIFT

| RANGE | KKK | KKG | KGK | KGG |
|---|---|---|---|---|
| 15000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 18000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 21000 | 0.9825 | 0.9875 | 0.9962 | 1.0000 |
| 24000 | 0.8487 | 0.8675 | 0.9650 | 1.0000 |
| 26000 | 0.6800 | 0.7625 | 0.9175 | 0.9987 |
| 32000 | 0.2287 | 0.5137 | 0.5237 | 0.8775 |

| RANGE | GKK | GKG | GGK | GGG |
|---|---|---|---|---|
| 15000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 18000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 21000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 24000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 26000 | 0.9962 | 1.0000 | 0.9975 | 1.0000 |
| 32000 | 0.9337 | 1.0000 | 0.9212 | 1.0000 |

2. 28-30 KTS NO POA-SHIFT

| RANGE | KKK | KKG | KGK | KGG |
|---|---|---|---|---|
| 15000 | 0.9987 | 1.0000 | 0.9975 | 1.0000 |
| 18000 | 0.8912 | 0.9250 | 0.9600 | 1.0000 |
| 21000 | 0.5950 | 0.7275 | 0.8287 | 1.0000 |
| 24000 | 0.2625 | 0.5350 | 0.6325 | 0.9687 |
| 26000 | 0.1225 | 0.4837 | 0.4350 | 0.8937 |
| 32000 | 0.0112 | 0.3925 | 0.1000 | 0.5950 |

| RANGE | GKK | GKG | GGK | GGG |
|---|---|---|---|---|
| 15000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 18000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 21000 | 0.9987 | 1.0000 | 0.9975 | 1.0000 |
| 24000 | 0.9687 | 1.0000 | 0.9537 | 1.0000 |
| 26000 | 0.9037 | 1.0000 | 0.8637 | 1.0000 |
| 32000 | 0.5637 | 0.9975 | 0.5400 | 1.0000 |

3. 28-30 KTS W POA-SHIFT

| RANGE | KKK | KKG | KGK | KGG |
|---|---|---|---|---|
| 15000 | 0.9987 | 1.0000 | 0.9975 | 1.0000 |
| 18000 | 0.8912 | 0.9250 | 0.9600 | 1.0000 |
| 21000 | 0.8337 | 0.8637 | 0.9537 | 1.0000 |
| 24000 | 0.7462 | 0.7787 | 0.9437 | 1.0000 |
| 26000 | 0.6887 | 0.7337 | 0.9550 | 1.0000 |
| 32000 | 0.5437 | 0.5775 | 0.9237 | 0.9737 |

| RANGE | GKK | GKG | GGK | GGG |
|---|---|---|---|---|
| 15000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 18000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 21000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 24000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 26000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 32000 | 0.9975 | 1.0000 | 0.9962 | 1.0000 |

Table VIII - PA-RESULTS FOR LOW/HIGH INITIAL SPEED FOR DDG KRIVAK-CLASS WITH 30° ASPECT

## 5. PA w/r to Detection-Delay

Another important assumption of the model refers to the delaytimes DETDEL and TRNDEL. TRNDEL is a relatively constant variable, which can be assessed from own-data. There seems no risk of underestimating this value. This, however, is not the case for DETDEL, the time before target reaction begins. If it turns out, that DETDEL with 10 seconds as the "worst" assumption is an underestimation, then the PA will increase, especially for the search patterns with the small activation-distance. This fact should be kept in mind, when the results are analyzed further. Table IX shows as an example the effect of two different values for DETDEL (10/20sec) on the PA for a DDG target with slow initial speed at an aspect-angle of 30°.

1. 28-30 KTS W POA *TDEL: 10 SEC*

| RANGE | KKK | KKG | KGK | KGG |
|---|---|---|---|---|
| 15000 | 0.9987 | 1.0000 | 0.9975 | 1.0000 |
| 18000 | 0.8912 | 0.9250 | 0.9600 | 1.0000 |
| 21000 | 0.8337 | 0.8637 | 0.9537 | 1.0000 |
| 24000 | 0.7462 | 0.7787 | 0.9437 | 1.0000 |
| 26000 | 0.6887 | 0.7337 | 0.9550 | 1.0000 |
| 28000 | 0.6687 | 0.7112 | 0.9275 | 0.9975 |
| 32000 | 0.5437 | 0.5775 | 0.9237 | 0.9737 |

2. 28-30 KTS W POA *TDEL: 20 SEC*

| RANGE | KKK | KKG | KGK | KGG |
|---|---|---|---|---|
| 15000 | 0.9975 | 0.9987 | 0.9975 | 1.0000 |
| 18000 | 0.9512 | 0.9625 | 0.9750 | 1.0000 |
| 21000 | 0.9037 | 0.9237 | 0.9650 | 1.0000 |
| 24000 | 0.8287 | 0.8525 | 0.9500 | 1.0000 |
| 26000 | 0.7575 | 0.8000 | 0.9487 | 0.9987 |
| 28000 | 0.7525 | 0.7725 | 0.9637 | 0.9987 |
| 32000 | 0.6375 | 0.6700 | 0.9337 | 0.9912 |

Table IX - PA-RESULTS FOR DIFFERENT DETDEL-VALUES
DDG KRIVAK-CLASS

## C. CONCLUSIONS AND RECOMMENDATIONS

Remember that the sensor and missile performance data used for the simulation do not reflect the actual performance characteristics of the systems used on FPEG-classes 143 and 148 (which are German classified). The following conclusions and recommendations are based on modified data, and it should not be inferred that they would have significance for an actual missile employment.

### 1. Conclusions

1.The discussion of the interdependence between PA and the target range revealed that the missile seeker activation-distance predominantly governs the range at which a PA of 0.99 is guaranteed. For all target types the choice of the larger activation-distance assures a larger engagement range and therefore reduces the own-risk; but the target discrimination capability is also significantly decreased. If the large activation-distance is not chosen for tactical reasons, then the size of the missile search-angle dominates the PA.
It also turned out that the acceleration capability of the target has a significant influence on the range at which it can be acquired by the missile seeker with a PA of at least 0.99. One can chose a larger engagement range when the target accelerates slowly and still have an acceptable own-risk.

2.The interdependence between PA and target aspect-angle generally showed that aspect-angles between 60° and 120° yield less favorable PA-values for the sector

combinations with the small activation-distance, and in particular for the patterns KKK and KKG. This behavior opposes the degradation of performance which occurs near 0° and 180° because the target radar cross section is minimum at these angles. The objective of this analysis was to investigate the effect of target evasive maneuvers on the PA of the missile seeker. At aspect-angles around 90° the search patterns KKK and KKG cover less of the target-motion envelope than for the other aspect-angles. This is of particular significance for fast reacting targets, as the Figures show. See the classified summary for a further discussion and recommendation.

3.The results for the POA-shifted PA as a function of the target range and the aspect-angles revealed a significant impact on the PA for all search patterns when the target range exceeded the RP5-range. This is especially true for the search pattern with the small activation-distance.

4.One of the assumptions of the simulation model referred to the "standard scenario", which excluded any effect on the detection range caused by ducting. If evaporation ducting conditions exist, then their effect on the engagement range can be exploited to advantage with this POA-shift. In this context see Tables III to VII.

5.The patterns GKG and GGG will always meet PA condition, but at the expense of TD; with the POA-shift GKK and GGK also meet the criterion, and the potential for TD is greatly improved.

6.Several variables, notably DETDEL have been conservatively estimated so that the conclusions are appropriate for the "worst case" scenario. To the extent that the variables have been underestimated, improvements in PA can be anticipated.

## 2. Recommendations

1.In all engagements use a POA-shift based on the estimated target performance data at ranges at and beyond the RP5-range. Tables of this shift are provided in the classified summary.

2.Avoid, if possible, target aspect-angles in the vicinity of 90°, if the small activation-distance is chosen, and if the target cross section is not a strong function of the aspect-angle.

3.If target range is appropriate, use the small activation-distance in multiship engagements.

4.Make realistic assessments of enemy's detection capabilities, because they strongly affect the PA.

## VII. ASSISTED TARGETING-SCHEME

The simulation model MM38-OTH is used to model engagements in which the target range is outside the FPBG radar horizon range, but within the practical attack range of the missile and when an extended platform (HC or RPV) is available to provide target data. The additional time delay for reporting data via UHF is included in the simulation model. The model MM38-OTH allows for the procedures which are appropriate for the engagement ranges investigated. The launch-platform, with the known range and bearing to the extended platform, can then calculate the target's position and the targeting solution. The position data for the extended platform are very accurate. The fire control radar is used for this purpose, which has the additional advantage, that its radiation might not be detected by hostile sensors due to the narrow beam characteristics. Therefore the presence of the launch platform might be concealed longer.

The previous sections illustrated the necessary assumptions for the general simulation model; some specific characteristics for this variant (MM38-OTH) already have been introduced in section V. and VI. The model determines the MOE for both the shifted and unshifted POA cases. Fig 28 depicts the geometry used for this model, and indicates the use of a POA-shift. The relevant data are presented in Table I.

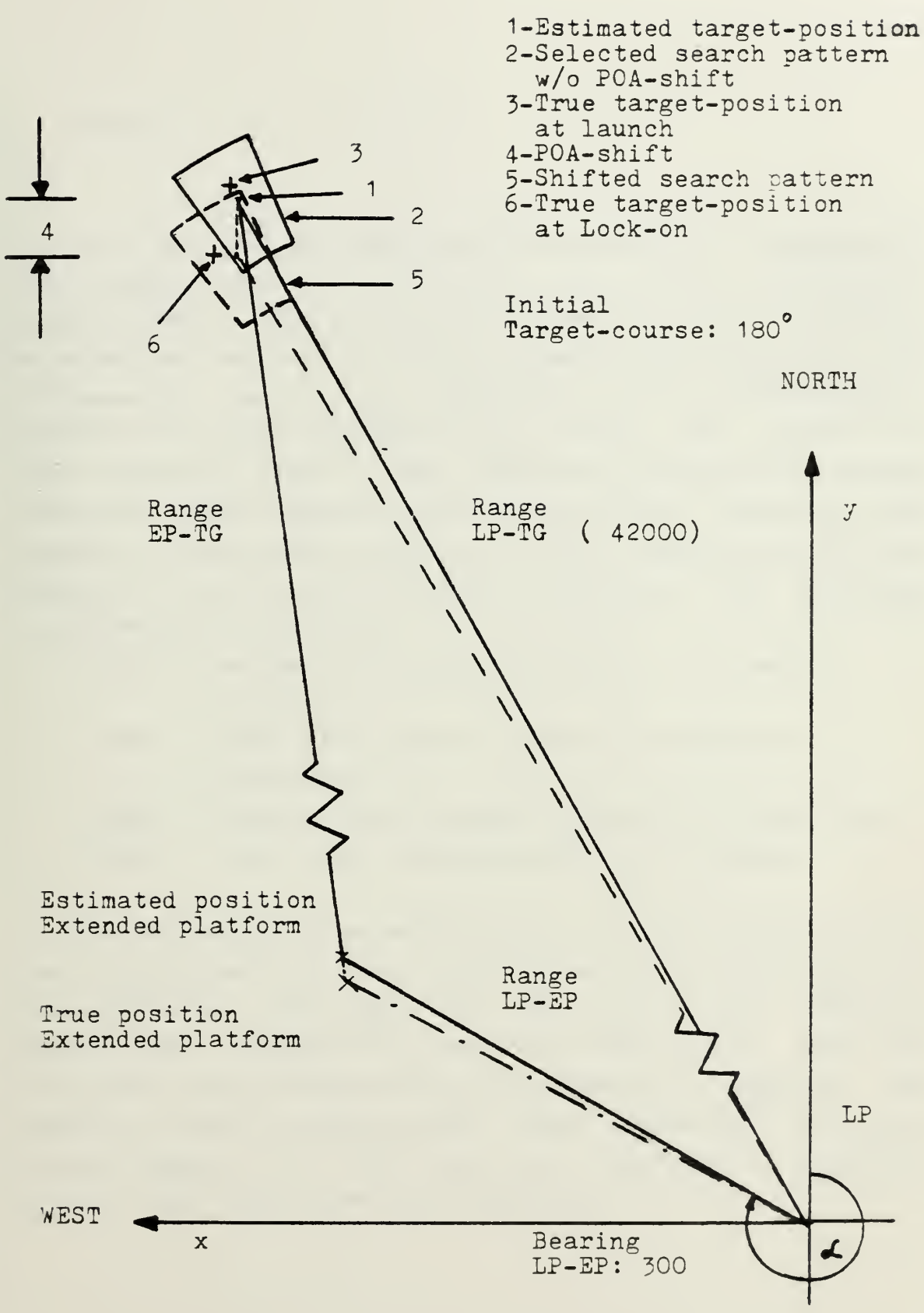



Figure 28 - TARGETING-GEOMETRY FOR THE OTH-SCHEME

## A. RESULTS

This part of the analysis investigates the influence of the extended platform location and sensor performance characteristics on the PA for the various search patterns. As expected, the factors which strongly affect the PA in the UAT-scenario also are dominant in the OTH-scenario. Therefore it seems unnecessary to discuss the effects of these factors again. Two additional factors also become important; they define the extended platform location with respect to the launch platform, and the target position with respect to the extended platform location. The following variables are introduced:

BLPEP - bearing from launch platform to extended platform,

RLPEP - range from launch platform to extended platform,

BEPTG - bearing from extended platform to target, and

REPTG - range from extended platform to target.

The UAT-scheme also showed that the DDG Krivak-Class, the rapidly reacting ship, illustrates all of the effects of the additional variables upon PA; so in the OTH-model results are reported only for this target type. Runs with the other target types would show a similar behavior. The possible target aspect-angles were restricted to three forward angles, 0°, 30°, and 60°, measured as negative angles, i.e. target bow is to the left.

1. PA w/r to HC-Location

Generally, for a given scenario, the smallest REPTG-value provides the best PA-value, because the HC-sensor is more accurate at shorter ranges. The estimated target ranges of 36000 and 40000 m provide trends similar to the results for 32000 m, but the PA is gradually decreasing, so that at an engagement range of about 40000 m only the GGG search pattern assures a PA of at least 0.99 for all HC-locations. The GKG pattern meets this requirement only for the BLPEP-values of 5° and 10° and the two closest target locations. Tables X and XI provide excerpts of PA-results for BLPEP-values of 10° and 20° as a comparison. In these tables no POA-shift is assumed. The aspect-angle is -30°, and SIGBE is constant at 1°.

DDG KRIVAK-CLASS 14-30 KTS NO PCA-SHIFT

1. RLPTG: 32000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 306 | 23200 | 0.55 | 0.64 | 0.76 | 0.92 |
| 14000 | 317 | 18660 | 0.57 | 0.67 | 0.75 | 0.90 |
| 18000 | 322 | 14400 | 0.51 | 0.61 | 0.74 | 0.88 |
| 22000 | 325 | 10230 | 0.49 | 0.60 | 0.72 | 0.87 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 306 | 23200 | 0.99 | 1.00 | 0.99 | 1.00 |
| 14000 | 317 | 18660 | 0.99 | 1.00 | 0.99 | 1.00 |
| 18000 | 322 | 14400 | 0.99 | 1.00 | 0.99 | 1.00 |
| 22000 | 325 | 10230 | 0.99 | 1.00 | 0.99 | 1.00 |

---

2. RLPTG: 36000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 301 | 27650 | 0.30 | 0.55 | 0.50 | 0.83 |
| 15000 | 315 | 21820 | 0.29 | 0.52 | 0.48 | 0.82 |
| 20000 | 322 | 16460 | 0.29 | 0.49 | 0.50 | 0.79 |
| 25000 | 326 | 11250 | 0.30 | 0.49 | 0.45 | 0.75 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 301 | 27650 | 0.93 | 1.00 | 0.89 | 1.00 |
| 15000 | 315 | 21820 | 0.91 | 0.99 | 0.91 | 1.00 |
| 20000 | 322 | 16460 | 0.90 | 0.99 | 0.89 | 1.00 |
| 25000 | 326 | 11250 | 0.89 | 0.96 | 0.91 | 1.00 |

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3. RLPTG: 40000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 296 | 32200 | 0.13 | 0.46 | 0.29 | 0.71 |
| 17000 | 316 | 23900 | 0.13 | 0.39 | 0.31 | 0.68 |
| 24000 | 323 | 16420 | 0.17 | 0.41 | 0.27 | 0.66 |
| 31000 | 327 | 9180 | 0.14 | 0.39 | 0.28 | 0.65 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 296 | 32200 | 0.71 | 0.99 | 0.71 | 1.00 |
| 17000 | 316 | 23900 | 0.72 | 0.97 | 0.71 | 1.00 |
| 24000 | 323 | 16420 | 0.73 | 0.94 | 0.75 | 1.00 |
| 31000 | 327 | 9180 | 0.66 | 0.90 | 0.71 | 1.00 |

Table X - PA-RESULTS FOR BLPEP OF 10°

DDG KRIVAK-CLASS 14-30 KTS NO POA-SHIFT

1. RLPTG: 32000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 299 | 21340 | 0.59 | 0.66 | 0.76 | 0.92 |
| 16000 | 307 | 18400 | 0.53 | 0.63 | 0.75 | 0.90 |
| 18000 | 313 | 15800 | 0.55 | 0.66 | 0.74 | 0.89 |
| 20000 | 317 | 13330 | 0.51 | 0.60 | 0.75 | 0.87 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 299 | 21340 | 0.99 | 1.00 | 0.99 | 1.00 |
| 16000 | 307 | 18400 | 0.99 | 1.00 | 0.99 | 1.00 |
| 18000 | 313 | 15800 | 0.99 | 1.00 | 0.99 | 1.00 |
| 20000 | 317 | 13330 | 0.99 | 1.00 | 1.00 | 1.00 |

---

2. RLPTG: 36000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 288 | 27170 | 0.30 | 0.51 | 0.49 | 0.82 |
| 18000 | 307 | 20700 | 0.30 | 0.50 | 0.50 | 0.82 |
| 22000 | 316 | 15600 | 0.30 | 0.51 | 0.49 | 0.80 |
| 26000 | 322 | 10930 | 0.30 | 0.49 | 0.48 | 0.76 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 288 | 27170 | 0.90 | 1.00 | 0.89 | 1.00 |
| 18000 | 307 | 20700 | 0.92 | 0.99 | 0.90 | 1.00 |
| 22000 | 316 | 15600 | 0.92 | 0.99 | 0.90 | 1.00 |
| 26000 | 322 | 10930 | 0.90 | 0.96 | 0.91 | 1.00 |

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3. RLPTG: 40000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 272 | 34620 | 0.13 | 0.40 | 0.30 | 0.71 |
| 20000 | 307 | 23000 | 0.12 | 0.40 | 0.25 | 0.67 |
| 26000 | 318 | 15500 | 0.16 | 0.41 | 0.29 | 0.66 |
| 32000 | 325 | 8700 | 0.14 | 0.38 | 0.27 | 0.64 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 272 | 34620 | 0.72 | 0.98 | 0.74 | 1.00 |
| 20000 | 307 | 23000 | 0.74 | 0.97 | 0.72 | 1.00 |
| 26000 | 318 | 15500 | 0.70 | 0.93 | 0.72 | 1.00 |
| 32000 | 325 | 8700 | 0.68 | 0.92 | 0.70 | 1.00 |

Table XI - PA-RESULTS FOR BLPEP OF 20°

## 2. PA w/r to HC-Sensor Data

The HC was deployed at four different bearings, 5°, 10°, 15°, and 20°, and at four different ranges from the launch platform (RLPEP). The range error of the HC-sensor is relative small ,and has a insignificant influence on the degree of overall uncertainty. Given a SIGBE of 1°, an estimated target range of 32000 m, a BLPEP-value of 5° and a decrease of the aspect-angle from -60° to 0°, the simulation results showed that the search patterns with the small activation-distance yield maximum PA-values. Increases from 0.56 to 0.75, 0.41 to 0.83, and from 0.62 t 0.75 are recorded for the patterns KKK, KKG, and KGG. The parameter combination KGK showed an almost opposite trend; its PA-value increased from 0.715 to 0.87, with the decrease of the aspect-angle from -60° to 0°. Similar trends for these four search pattern are reported for the BLPEP of 10° to 20°.

The parameter combinations based on the large activation-distance showed that a bearing greater than 15° has a degrading effect on the PA. For BLPEP of 5° to 15° the search patterns GGK and GGG produce acceptable PA-values for all four ranges; the minimum value for GKK and GKG is 0.975, which drops to 0.91 for a bearing of 20° at the target range of 36000 m. The employment of an HC-sensor with a bearing error of 2° or even 3° significantly decrease the PA-values for all search parameter combinations over all values of REPTG; with these bearing errors the pattern GGG produces acceptable results only at 10000 m, the others fail at all ranges.

Tables XII to XIV show the influence on the PA of different values for SIGBE at a constant BLPEP-value of 10° and a constant aspect-angle of -30°. Table XV compares the PA-values for an aspect-angle of 0° and SIGBE of 1°. The POA has not been shifted.

DDG KRIVAK-CLASS 14-30 KTS NO PCA-SHIFT

1. RLPTG: 32000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 317 | 18670 | 0.46 | 0.54 | 0.67 | 0.82 |
| 17000 | 321 | 15500 | 0.44 | 0.49 | 0.64 | 0.75 |
| 20000 | 324 | 12300 | 0.37 | 0.44 | 0.60 | 0.71 |
| 23000 | 326 | 9200 | 0.36 | 0.42 | 0.56 | 0.66 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 317 | 18670 | 0.97 | 0.98 | 0.99 | 1.00 |
| 17000 | 321 | 15500 | 0.94 | 0.94 | 0.99 | 1.00 |
| 20000 | 324 | 12300 | 0.90 | 0.90 | 0.99 | 1.00 |
| 23000 | 326 | 9200 | 0.84 | 0.84 | 0.99 | 1.00 |

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2. RLPTG: 36000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 314 | 23000 | 0.26 | 0.44 | 0.44 | 0.73 |
| 18000 | 320 | 18600 | 0.26 | 0.43 | 0.41 | 0.67 |
| 22000 | 324 | 14360 | 0.23 | 0.36 | 0.39 | 0.60 |
| 26000 | 326 | 10220 | 0.23 | 0.36 | 0.39 | 0.58 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 314 | 23000 | 0.86 | 0.93 | 0.90 | 1.00 |
| 18000 | 320 | 18600 | 0.84 | 0.91 | 0.93 | 1.00 |
| 22000 | 324 | 14360 | 0.79 | 0.83 | 0.93 | 1.00 |
| 26000 | 326 | 10220 | 0.76 | 0.81 | 0.90 | 0.99 |

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3. RLPTG: 40000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 310 | 27240 | 0.16 | 0.40 | 0.28 | 0.64 |
| 20000 | 320 | 20650 | 0.16 | 0.36 | 0.26 | 0.58 |
| 26000 | 325 | 14340 | 0.13 | 0.30 | 0.22 | 0.50 |
| 32000 | 328 | 8160 | 0.14 | 0.29 | 0.26 | 0.50 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 310 | 27240 | 0.68 | 0.90 | 0.75 | 1.00 |
| 20000 | 320 | 20650 | 0.65 | 0.85 | 0.73 | 1.00 |
| 26000 | 325 | 14340 | 0.59 | 0.75 | 0.74 | 0.97 |
| 32000 | 328 | 8160 | 0.54 | 0.71 | 0.72 | 0.96 |

Table XII - PA-RESULTS FOR SIGBE OF 1°
BLPEP 10°/ASPECT-ANGLE -30°

DDG KRIVAK-CLASS 14-30 KTS NO PCA-SHIFT

1. RLPTG: 32000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 306 | 23200 | 0.55 | 0.64 | 0.76 | 0.92 |
| 14000 | 317 | 18660 | 0.57 | 0.67 | 0.75 | 0.90 |
| 18000 | 322 | 14400 | 0.51 | 0.61 | 0.74 | 0.88 |
| 22000 | 325 | 10230 | 0.49 | 0.60 | 0.72 | 0.87 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 306 | 23200 | 0.99 | 1.00 | 0.99 | 1.00 |
| 14000 | 317 | 18660 | 0.99 | 1.00 | 0.99 | 1.00 |
| 18000 | 322 | 14400 | 0.99 | 1.00 | 0.99 | 1.00 |
| 22000 | 325 | 10230 | 0.99 | 1.00 | 0.99 | 1.00 |

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2. RLPTG: 36000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 301 | 27650 | 0.30 | 0.55 | 0.50 | 0.83 |
| 15000 | 315 | 21820 | 0.29 | 0.52 | 0.48 | 0.82 |
| 20000 | 322 | 16460 | 0.29 | 0.49 | 0.50 | 0.79 |
| 25000 | 326 | 11250 | 0.30 | 0.49 | 0.45 | 0.75 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 301 | 27650 | 0.93 | 1.00 | 0.89 | 1.00 |
| 15000 | 315 | 21820 | 0.91 | 0.99 | 0.91 | 1.00 |
| 20000 | 322 | 16460 | 0.90 | 0.99 | 0.89 | 1.00 |
| 25000 | 326 | 11250 | 0.89 | 0.96 | 0.91 | 1.00 |

---

3. RLPTG: 40000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 296 | 32200 | 0.13 | 0.46 | 0.29 | 0.71 |
| 17000 | 316 | 23900 | 0.13 | 0.39 | 0.31 | 0.68 |
| 24000 | 323 | 16420 | 0.17 | 0.41 | 0.27 | 0.66 |
| 31000 | 327 | 9180 | 0.14 | 0.39 | 0.28 | 0.65 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 296 | 32200 | 0.71 | 0.99 | 0.71 | 1.00 |
| 17000 | 316 | 23900 | 0.72 | 0.97 | 0.71 | 1.00 |
| 24000 | 323 | 16420 | 0.73 | 0.94 | 0.75 | 1.00 |
| 31000 | 327 | 9180 | 0.66 | 0.90 | 0.71 | 1.00 |

Table XIII - PA-RESULTS FOR SIGBE OF 2°
BLPEP 10°/ASPECT-ANGLE -30°

DDG KRIVAK-CLASS 14-30 KTS NO PCA-SHIFT

1. RLPTG: 32000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 317 | 18700 | 0.39 | 0.46 | 0.57 | 0.70 |
| 17000 | 321 | 15500 | 0.35 | 0.40 | 0.53 | 0.61 |
| 20000 | 324 | 12300 | 0.27 | 0.33 | 0.48 | 0.56 |
| 23000 | 326 | 9200 | 0.26 | 0.31 | 0.44 | 0.51 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 317 | 18700 | 0.88 | 0.89 | 1.00 | 1.00 |
| 17000 | 321 | 15500 | 0.82 | 0.82 | 0.99 | 1.00 |
| 20000 | 324 | 12300 | 0.75 | 0.76 | 0.97 | 0.98 |
| 23000 | 326 | 9200 | 0.68 | 0.68 | 0.95 | 0.95 |

---

2. RLPTG: 36000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 314 | 23000 | 0.24 | 0.39 | 0.39 | 0.62 |
| 18000 | 320 | 18600 | 0.22 | 0.35 | 0.36 | 0.56 |
| 22000 | 324 | 14360 | 0.18 | 0.29 | 0.32 | 0.47 |
| 26000 | 326 | 10220 | 0.16 | 0.26 | 0.29 | 0.44 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 314 | 23000 | 0.78 | 0.85 | 0.90 | 1.00 |
| 18000 | 320 | 18600 | 0.72 | 0.77 | 0.92 | 0.98 |
| 22000 | 324 | 14360 | 0.61 | 0.66 | 0.91 | 0.96 |
| 26000 | 326 | 10220 | 0.58 | 0.62 | 0.85 | 0.93 |

---

3. RLPTG: 40000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 310 | 27240 | 0.18 | 0.37 | 0.26 | 0.56 |
| 20000 | 320 | 20640 | 0.14 | 0.30 | 0.23 | 0.49 |
| 26000 | 325 | 14340 | 0.01 | 0.24 | 0.18 | 0.40 |
| 32000 | 328 | 8200 | 0.11 | 0.22 | 0.21 | 0.37 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 310 | 27240 | 0.62 | 0.82 | 0.77 | 1.00 |
| 20000 | 320 | 20640 | 0.56 | 0.72 | 0.74 | 0.97 |
| 26000 | 325 | 14340 | 0.49 | 0.61 | 0.71 | 0.90 |
| 32000 | 328 | 8200 | 0.43 | 0.55 | 0.65 | 0.85 |

Table XIV - PA-RESULTS FOR SIGBE OF 3°
BLPEP 10°/ASPECT-ANGLE -30°

DDG KRIVAK-CLASS 14-30 KTS NO PCA-SHIFT

1. RLPTG: 32000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 336 | 23200 | 0.65 | 0.83 | 0.73 | 0.99 |
| 14000 | 346 | 18700 | 0.61 | 0.78 | 0.77 | 0.99 |
| 18000 | 352 | 14400 | 0.59 | 0.75 | 0.71 | 0.96 |
| 22000 | 355 | 10230 | 0.53 | 0.68 | 0.71 | 0.93 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 336 | 23200 | 0.98 | 1.00 | 0.96 | 1.00 |
| 14000 | 346 | 18700 | 0.88 | 1.00 | 0.97 | 1.00 |
| 18000 | 352 | 14400 | 0.97 | 1.00 | 0.96 | 1.00 |
| 22000 | 355 | 10230 | 0.97 | 1.00 | 0.97 | 1.00 |

---

2. RLPTG: 36000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 331 | 27650 | 0.33 | 0.65 | 0.52 | 0.94 |
| 15000 | 345 | 21820 | 0.33 | 0.64 | 0.51 | 0.92 |
| 20000 | 351 | 16460 | 0.29 | 0.58 | 0.42 | 0.87 |
| 25000 | 355 | 11250 | 0.29 | 0.56 | 0.43 | 0.81 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 331 | 27650 | 0.85 | 1.00 | 0.81 | 1.00 |
| 15000 | 345 | 21820 | 0.86 | 1.00 | 0.84 | 1.00 |
| 20000 | 351 | 16460 | 0.85 | 1.00 | 0.83 | 1.00 |
| 25000 | 355 | 11250 | 0.85 | 0.98 | 0.85 | 1.00 |

---

3. RLPTG: 40000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 326 | 32200 | 0.13 | 0.47 | 0.29 | 0.83 |
| 17000 | 345 | 23900 | 0.12 | 0.44 | 0.29 | 0.78 |
| 24000 | 353 | 16500 | 0.13 | 0.43 | 0.27 | 0.75 |
| 31000 | 357 | 9180 | 0.16 | 0.42 | 0.27 | 0.69 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 326 | 32200 | 0.63 | 1.00 | 0.62 | 1.00 |
| 17000 | 345 | 23900 | 0.65 | 0.99 | 0.62 | 1.00 |
| 24000 | 353 | 16500 | 0.63 | 0.98 | 0.61 | 1.00 |
| 31000 | 357 | 9180 | 0.61 | 0.95 | 0.63 | 1.00 |

Table XV - PA-RESULTS FOR SIGBE OF 1°

BLPEP 10°/ASPECT-ANGLE 0°

3. PA w/r to POA-shift

A POA-shift also improves the PA-results for all parameter combinations for this targeting-scheme. The results are very similar to those for the UAT-scheme. In particular, the use of the search pattern with the small activation-distance has become more realistic, because PA-values exceeding 0.90 are generated. Following the observed overall trend the use of less accurate sensors generally degrades the PA.

A very important result, however, is that a POA-shift applied with a $2^{o}$ inaccuracy yields a better PA than obtainable with a $1^{o}$ inaccuracy without the shift. This is also true for the $3^{o}$ inaccuracy sensor.

Table XVI and XVII show the PA-values generated by the POA-shift for a SIGBE-value of $1^{o}$ and $2^{o}$, and for BLPEP of $10^{o}$ and an aspect-angle of $-30^{o}$. Table XII should be used as a comparison, because those data were obtained without a POA-shift.

DDG KRIVAK-CLASS 14-30 KTS WITH POA-SHIFT

1. RLPTG: 32000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 306 | 23200 | 0.76 | 0.78 | 0.95 | 0.98 |
| 14000 | 317 | 18700 | 0.77 | 0.79 | 0.93 | 0.97 |
| 18000 | 322 | 14400 | 1.00 | 1.00 | 1.00 | 1.00 |
| 22000 | 325 | 10230 | 1.00 | 1.00 | 1.00 | 1.00 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 306 | 23200 | 1.00 | 1.00 | 1.00 | 1.00 |
| 14000 | 317 | 18700 | 1.00 | 1.00 | 1.00 | 1.00 |
| 18000 | 322 | 14400 | 0.73 | 0.74 | 0.91 | 0.94 |
| 22000 | 325 | 10230 | 0.65 | 0.67 | 0.90 | 0.93 |

---

2. RLPTG: 36000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 301 | 27650 | 0.72 | 0.74 | 0.94 | 0.97 |
| 15000 | 315 | 21820 | 0.65 | 0.67 | 0.90 | 0.95 |
| 20000 | 322 | 16500 | 0.62 | 0.64 | 0.87 | 0.91 |
| 25000 | 326 | 11250 | 0.60 | 0.62 | 0.85 | 0.88 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 301 | 27650 | 1.00 | 1.00 | 1.00 | 1.00 |
| 15000 | 315 | 21820 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20000 | 322 | 16460 | 1.00 | 1.00 | 1.00 | 1.00 |
| 25000 | 326 | 11250 | 0.98 | 0.98 | 1.00 | 1.00 |

---

3. RLPTG: 40000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 10000 | 296 | 32200 | 0.59 | 0.62 | 0.90 | 0.95 |
| 17000 | 316 | 23900 | 0.54 | 0.57 | 0.85 | 0.89 |
| 24000 | 323 | 16420 | 0.53 | 0.56 | 0.80 | 0.84 |
| 31000 | 327 | 9180 | 0.49 | 0.52 | 0.77 | 0.81 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 10000 | 296 | 32200 | 1.00 | 1.00 | 0.99 | 1.00 |
| 17000 | 316 | 23900 | 1.00 | 1.00 | 1.00 | 1.00 |
| 24000 | 323 | 16420 | 0.98 | 0.98 | 1.00 | 1.00 |
| 31000 | 327 | 9180 | 0.95 | 0.95 | 1.00 | 1.00 |

Table XVI - PA-RESULTS W/R TO POA-SHIFT
SIGBE 1°/BLPEP 10°/ASPECT-ANGLE -30°

DDG KRIVAK-CLASS 14-30 KTS WITH POA-SHIFT

1. RLPTG: 32000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 317 | 18670 | 0.59 | 0.60 | 0.85 | 0.87 |
| 17000 | 321 | 15450 | 0.54 | 0.55 | 0.79 | 0.82 |
| 20000 | 324 | 12300 | 0.47 | 0.49 | 0.74 | 0.76 |
| 23000 | 326 | 9200 | 0.45 | 0.46 | 0.70 | 0.71 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 317 | 18670 | 0.99 | 0.99 | 1.00 | 1.00 |
| 17000 | 321 | 15450 | 0.96 | 0.96 | 1.00 | 1.00 |
| 20000 | 324 | 12300 | 0.94 | 0.94 | 1.00 | 1.00 |
| 23000 | 326 | 9200 | 0.87 | 0.87 | 1.00 | 1.00 |

---

2. RLPTG: 36000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 314 | 23000 | 0.56 | 0.58 | 0.80 | 0.84 |
| 18000 | 320 | 18600 | 0.52 | 0.53 | 0.77 | 0.80 |
| 22000 | 324 | 14360 | 0.41 | 0.42 | 0.68 | 0.71 |
| 26000 | 326 | 10200 | 0.40 | 0.42 | 0.65 | 0.67 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 314 | 23000 | 0.98 | 0.98 | 1.00 | 1.00 |
| 18000 | 320 | 18600 | 0.94 | 0.94 | 1.00 | 1.00 |
| 22000 | 324 | 14360 | 0.89 | 0.89 | 1.00 | 1.00 |
| 26000 | 326 | 10200 | 0.85 | 0.85 | 1.00 | 0.99 |

---

3. RLPTG: 40000 M

| REPTG | BEPTG | RLPEP | KKK | KKG | KGK | KGG |
|---|---|---|---|---|---|---|
| 14000 | 310 | 27240 | 0.52 | 0.55 | 0.77 | 0.80 |
| 20000 | 320 | 20640 | 0.43 | 0.45 | 0.70 | 0.73 |
| 26000 | 325 | 14340 | 0.35 | 0.37 | 0.61 | 0.63 |
| 32000 | 328 | 8160 | 0.36 | 0.36 | 0.59 | 0.60 |

| REPTG | BEPTG | RLPEP | GKK | GKG | GGK | GGG |
|---|---|---|---|---|---|---|
| 14000 | 310 | 27240 | 0.98 | 0.98 | 1.00 | 1.00 |
| 20000 | 320 | 20640 | 0.91 | 0.91 | 1.00 | 1.00 |
| 26000 | 325 | 14340 | 0.82 | 0.82 | 0.98 | 0.98 |
| 32000 | 328 | 8160 | 0.74 | 0.74 | 0.99 | 0.99 |

Table XVII - PA-RESULTS W/R TO POA-SHIFT
SIGBE 2°/BLPEP 10°/ASPECT-ANGLE -30°

## B. CONCLUSIONS/RECOMMENDATIONS

The results obtained reflect the effects of the modified - unclassified - parameters. As already has been pointed out, the various parameters in general have the same effects as observed in the UAT-model; so only especially pertinent additional results will be discussed.

### 1. Conclusions

1.The sensor inaccuracy requires that the extended platform be placed as near to the target as possible. On the other hand the appearance of an HC or an RPV suggests to the target that a missile attack is imminent. If the target initiates evasive maneuvers, of course the targeting-solution is degraded.

2.The stationing of the extended platform at larger angles than 15° to either side of the estimated bearing from the launch platform to the target degrades the PA for all search patterns. If the tactical situation permits, use of at most 10° is recommended.

3.Bow target aspect-angles generally provide higher PA-values for a constant radar cross section target.

4. The POA-shift appears to be even more productive in an OTH-targeting tactical situation.

5.If the tactical scenario permits "optimum" location of the extended platform, then at these ranges a POA-shift allows the choice of a smaller search sector, and TD can be dramatically improved.

## 2. Recommendations

1.Execute tactical exercises to assure efficient cooperation between launch platform and extended platform and to reduce delaytimes.

2. Station the extended platform prudently to compromise between screening the presence of a SSM launch platform and increasing the PA.

3.Use the POA-shift to counterbalance the degraded sensor quality of the extended platform. This procedure might even lead to relaxed performance criteria and thereby reduce procurement costs.

# APPENDIX A

## TARGET-MOTION-ANALYSIS

The purpose of this appendix is to analyze the actual target-motion within a given time-period, and its constraints due to several factors.

After a general derivation of a reachable set of locations, specific analyses are made for certain WPN-surface vessels, which yield the maximum values in crossrange- and downrange-deviations from the assumed target-position at launch-time, the point of aim ( POA ).

Certain tactical situations prohibit the use of some of the available sector-parameter combinations. Therefore the success of the missile-engagement versus the target(s) can be considered as directly dependent on the envelope of target positions accessible prior to Lock-on (with or without changes in course/speed).

Intelligence reports, and enemy contact reports by coastal radar stations and/or by extended platforms normally assure the identity or at least the type(s) of the enemy force, if not even the class(es). With this knowledge and under the assumption that an immediate missile-employment is not necessary, the possible limits of the enemy target-motion should be evaluated based on the last known target-motion and target-position. It is reasonable to assume, that with this procedure an improvement of TA or even TD - avoiding an attack on unintended targets - can be

achieved without reduction of the required high acquisition-probability.

Relevant analyses commonly assume that the target's course is uniformly distributed from 0° to 360°, and its speed is also uniformly distributed within a reasonable range. This assumption leads to the unnecessary inclusion of unrealistic target-motions in the consideration leading to the choice of the relevant search-sector parameters. Even the most modern ships, due to their construction characteritsics, are restricted to a turning-rate of not exceeding about 3°/second.

This fact implies that a target ship's course is not uniformly distributed over the above mentioned course range. This simplifying and also disadvantageous assumption means that more area has to be covered by the search-sector than actually necessary to assure the required acquisition-probability.

As already pointed out in section III.C.2, this simulation is designed to investigate the influence of course/speed-changes on the PA. In this context it is reasonable to assume that surface forces under missile attack will use all their capabilities to achieve a maximum turning-rate as well as a maximum acceleration, and thereby maximize own defense-weapon concentration and/or to possibly evade the search-sector of the attacking missiles. These capabilities result in a reachable set of possible positions based on the estimated target course and speed. This set is subject to maximum possible course/speed-changes.

The model for this reachable set is based on the analysis for aircraft in [6] , however modified by the following assumptions concerning the target-motion :

1. Any lateral maneuver in the xy-plane is caused by a constant turning-rate at a constant speed (sea-surface is considered as the xy-plane ).

2. Only one turning maneuver is allowed during the relevant time-period.

3. The turning maneuver is made in the beginning of the time-period with maximum turning-rate followed by continued motion in a straight line on the new course at maximum speed.

4. Speed variation due to acceleration is averaged, so that the speed is assumed to be constant throughout the time-period.

5. Average speed and turning maneuvers are assumed to be independent.

The first three assumptions imply that a lateral maneuver must take place on a circular arc and that any movement in the xy-plane is either a straight line or a circular arc with an attached, variable length straight course. These two kinds of maneuvers yield locations on an outer boundary of the reachable set. It satisfies the enemy's requirement to withdraw as far as possible from his position upon which the launch might presumably be based. The time available for this maneuver depends on the time of missile detection, and the expected Lock-on-Time, which, however, can not exactly be determined by the enemy.

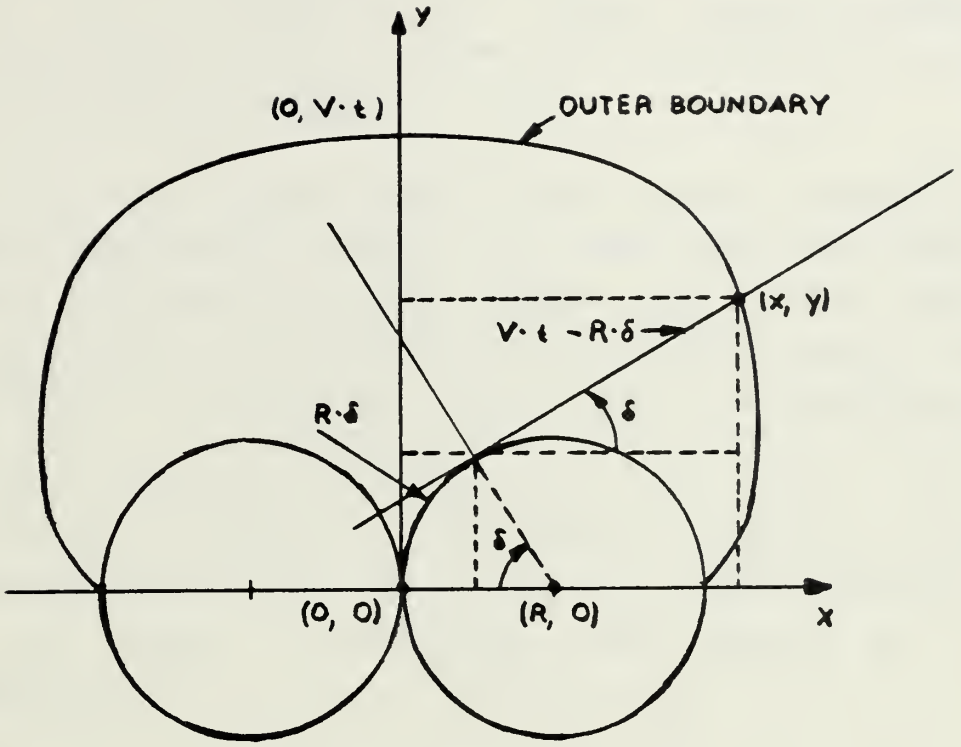


Figure 29 - THE CONSTRUCTION OF THE OUTER BOUNDARY

Assuming the initial velocity vector is pointing along the y-axis, the outer boundary of the reachable set is symmetric about the y-axis, as shown in Fig 30. DELTA ( ) is the angle in radians turned through by the target before deciding to proceed on a straight course. The x, y coordinates of half the outer boundary as a function of ($\delta$) are then given by

$$x(\delta) = R*(1-\cos\delta) + (v*t-R*\delta)*\sin\delta, \text{ and}$$

$$y(\delta) = R*\sin\delta + (v*t-R*\delta)*\cos\delta .$$

The maximum length of the distance travelled is v*t, where v corresponds to the missile speed, and t is the time, at which the missile locks on the target; R is the minimum turn radius, based on a 90° turn. If the delay due to the assumed reaction-time is to be included, then $y(\delta)$ must be

increased by the additional distance travelled. This outer boundary then represents the maximum possible realistic target-positions within the time from launching the missile until the expected Lock-on.

The TA - analysis has to come up with search-sector parameter combinations, which will cover a maximum number of points of this set as well as points within the position area generated by the boundary - in case the target should not accelerate as expected. Fig 31 shows the comparison of such a set, a circular position area based on the maximum length of the distance travelled as the radius, and the search sector combination GKK without a shift of the POA. Performance data for the DDG target (low initial speed) at a range of 26000 m (RP5-range) are assumed for this illustration.

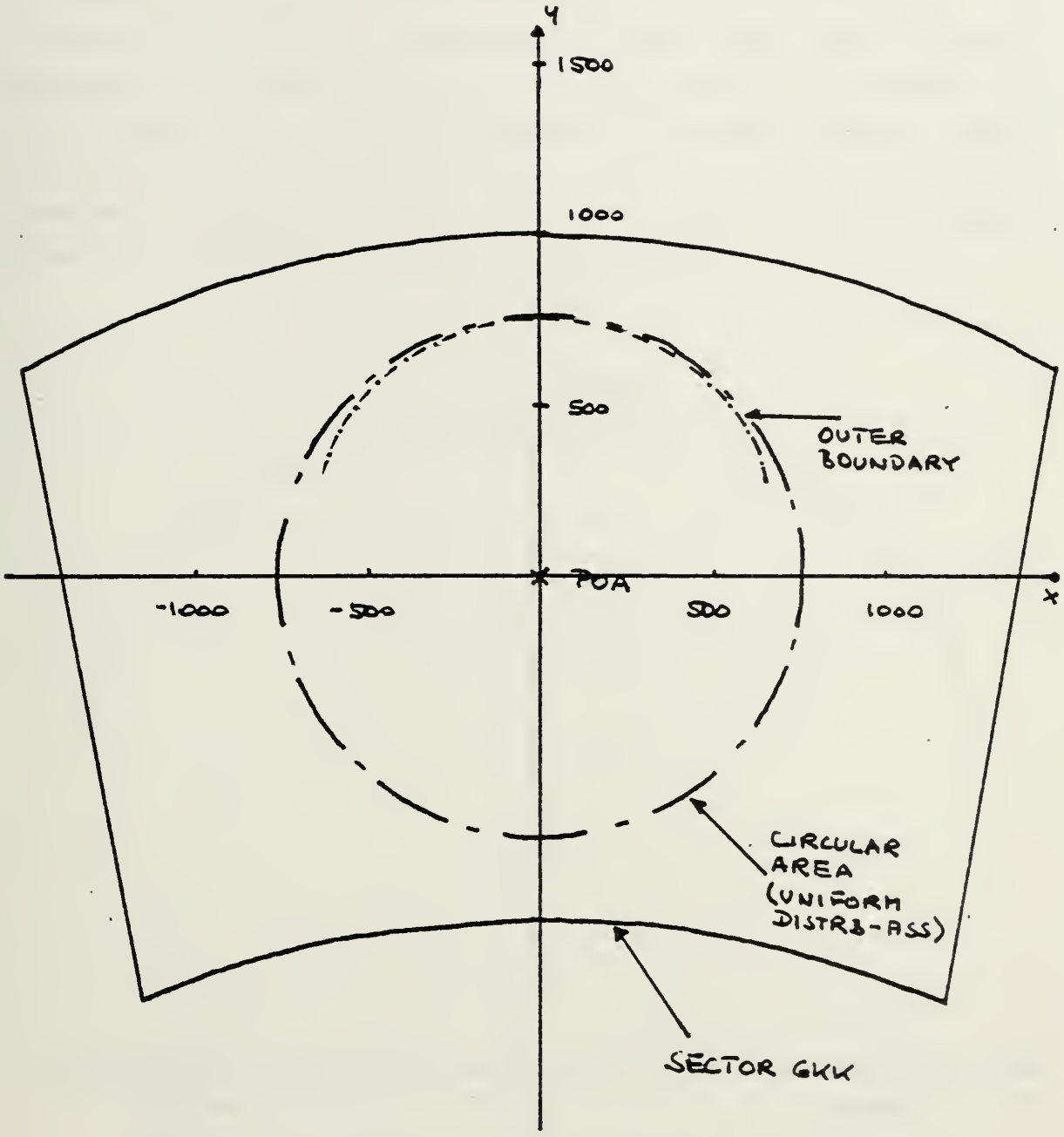


Figure 30 - THE COMPARISON OF TWO POSITION AREAS AND A SEARCH-SECTOR

The outer boundary set only encloses about 60% of the area obtained from the usual analysis; it is also evident that target-discrimination is facilitated by utilizing the reachable set for the analysis. If less time until expected Lock-on is "available", the outer boundary is reduced and vice versa. It is obvious that for the other target types corresponding relations hold. Fig 30 shows an outer boundary for the DDG target at the respective RP1-range, when the activation-distance K is chosen.

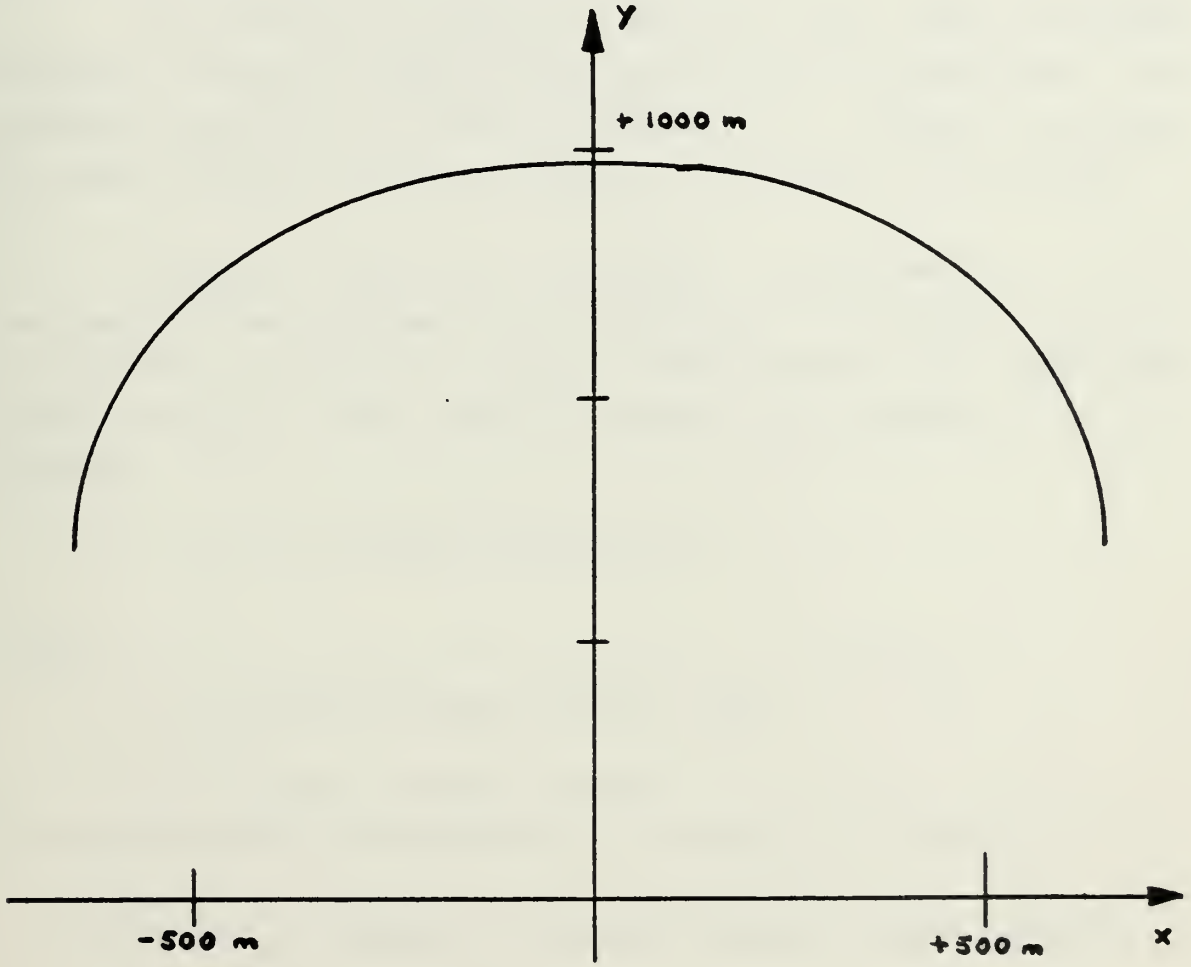


Figure 31 - OUTER BOUNDARY FOR DDG KRIVAK-CLASS

# APPENDIX B

## ELECTROMAGNETIC RADIATION RANGE PREDICTION

This section provides a method from which various relevant detection ranges were derived for the analysis. As already pointed out in section III.A., no surface ducting or other effects on electromagnetic radiation are assumed.

Typical radar and infrared performance in a non-ducting environment is dependent on sensor antenna height and the amount of target area above the resulting radar horizon. The radar horizon is defined to be (in meters)

$$R_H = 4.115*(\sqrt{A} + \sqrt{H})*1000.0$$

where

A = sensor antenna height, and

H = height of the target.

The probability of detection at range $R_H$ is assumed to be

0.1 when $H_1$ = height of target's height sensor antenna,

0.5 when $H_2$ = height of target's bridge, and

0.9 when $H_3$ = height of target's maindeck.

The respective ranges from the radar horizon formula are denoted as RP1, RP5, and RP9. Pertinent parameters used in

the sensor performance range prediction are [3].

| HEIGHT / SHIP | A | H1 | H2 | H3 |
|---|---|---|---|---|
| FPBG-143- | 10.7 | 0.0 | 0.0 | 0.0 |
| DDG | 21.7 | 21.7 | 10.1 | 4.6 |
| PFG | 14.0 | 14.0 | 9.8 | 3.1 |
| FPBG-OSA- | 9.2 | 9.2 | 4.6 | 3.1 |
| LSM | 17.7 | 17.7 | 8.5 | 3.1 |

DIMENSION: M

The resulting approximated $R_H$-values of the FPBG 143-Class towards the WPN surface combattants (radar sensor) are as fcllows:

| TYPE / RANGE | DDG | PFG | FPBG | LSM |
|---|---|---|---|---|
| RP9 | 22000 | 20000 | 20000 | 20000 |
| RP5 | 26000 | 26000 | 22000 | 25000 |
| RP1 | 32000 | 29000 | 26000 | 29000 |

DIMENSION: M

It is possible that the WPN have sensors available which might detect the attacking missile very early, even

before the SSM actively radiates in its search mode. The radar horizon formula yields the following against a MM 38 missile which is assumed to fly at an average altitude of 10 m. This altitude is considered to be equivalent tc the previously defined altitude $H_2$.

The resulting $R_H$-values (RNG5) are as follows:

- DDG..: 31500 m
- PFG..: 28000 m
- FPBG.: 25000 m
- LSM..: 28500 m.

these values are used to determine the possible target reaction-time for the UAT-scheme. $R_H$-values are based on the line-of-sight condition, which provides a lower bound on electromagnetic radiation performance. The upper bound is a result of ducting, primarily by way of evaporative duct. Reference [7] provides a method of predicting the existence of this duct-type.

# APPENDIX C

## SIMULATION-MODEL MM38-UAT

```
      DIMENSION THETA(2), ACTIV(2), L(2), TDEL(2)                       MM38  10
      DIMENSION DEG1(13), A1(13), BETA1(13)                             MM38  20
      DIMENSION RANGE1(22), RX1(22)                                     MM38  30
      DIMENSION TAU1(2), TAU2(2), RTEST1(2), RTEST2(2)                  MM38  40
      DIMENSION P(22,2,2,2,2), PD(22,2,2,2,2), TR(22,2,2,2)            MM38  50
      DIMENSION PX(2,22,2,2,2,2)                                        MM38  60
      DIMENSION ZDET1(2), ZPCS1(2), ZLOCK(2)                            MM38  70
      REAL L                                                            MM38  80
C                                                                       MM38  90
C                                                                       MM38 100
      DATA NROT,NA,NT,NL/13,2,2,2/                                      MM38 110
      DATA RP9,RP5,RP1/22000.0,26000.0,32000.0/                         MM38 120
      DATA RNG5/31500.0/                                                MM38 130
      DATA DETDEL,TRNDEL/20.0,10.0/                                     MM38 140
      DATA TDEL/5.90,7.90/                                              MM38 150
      DATA TLAUN/2.5/                                                   MM38 160
      DATA PI,RADIAN,CF/3.141593,0.017453,57.295779/                    MM38 170
      DATA CFS/0.51444/                                                 MM38 180
      DATA SIGVM,SIGDEL/1.5,1.5/                                        MM38 190
      DATA SIGBL,SIGRL/0.25,120.0/                                      MM38 200
      DATA SIGCL,SIGSL/3.5,0.4/                                         MM38 210
      DATA VMISS/315.0/                                                 MM38 220
      DATA WSPEED,WDIREC/0.0,315.0/                                     MM38 230
C                                                                       MM38 240
C                                                                       MM38 250
   20 FORMAT (2F10.2)                                                   MM38 260
   30 FORMAT (3F10.2,F10.4)                                             MM38 270
   40 FORMAT ('1','SIMULATION - RUNS  - ',I3,' -',//)                   MM38 280
   50 FORMAT ('0',15X,'FIRST LETTER REFERS TO ACTIVATION-DISTANCE',/)   MM38 290
   60 FORMAT ('0',15X,'SECOND LETTER REFERS TO SEARCH-ANGLE',/)         MM38 300
   70 FORMAT ('0',15X,'THIRD LETTER REFERS TO SEARCH-DEPTH',/)          MM38 310
   80 FORMAT ('0',T47,'** TARGET - DDG KRIVAK-CLASS **',//)             MM38 320
   90 FORMAT ('0',5X,'TARGET COURSE - 360 DEGREES -',//)                MM38 330
  100 FORMAT ('0',10X,'V1 (KN):',F5.1,5X,'VMAX (KN):',F5.1,5X,'ACCELERATMM38 340
     1ION (M/SEC**2):',F6.3,5X,'TURN-RATE (DEG/SEC):',F3.1,//)          MM38 350
  110 FORMAT ('0',10X,'* DATA - COURSE,SPEED,BEARING,RANGE - ARE ESTIMATMM38 360
     1ES.WIND EFFECTS ARE TAKEN INTO ACCOUNT. *',//)                    MM38 370
  120 FORMAT ('1',5X,'* ASPECT-ANGLE:',F7.1,' *',5X,'BEARING:',F6.1,/)  MM38 380
  130 FORMAT ('0',10X,'ACTIVATION - DISTANCE: K',///,7X,'RANGE',T22,'KKKMM38 390
     1',T30,'KKG',T42,'KGK',T50,'KGG',//)                               MM38 400
  140 FORMAT (' ',5X,F7.1,T21,F6.4,T29,F6.4,T41,F6.4,T49,F6.4)          MM38 410
  150 FORMAT (//)                                                       MM38 420
  160 FORMAT (///)                                                      MM38 430
C                                                                       MM38 440
```

```
C                                                                       MM38  450
      CALL OVFLOW                                                       MM38  460
      NCCLRS = 230876                                                   MM38  470
      NSPD = 1087539                                                    MM38  480
      NSPD1 = 58730214                                                  MM38  490
      NDELAY = 8630297                                                  MM38  500
      NDET1 = 732015                                                    MM38  510
      NLOCK = 41207                                                     MM38  520
      NTIME1 = 234780                                                   MM38  530
      NTURN1 = 830241                                                   MM38  540
      ESTCRS = 0.0                                                      MM38  550
      NSIM = 400                                                        MM38  560
      REAL = NSIM                                                       MM38  570
      IFLAGP = 0                                                        MM38  580
      NX5 = (RP5-14000.0)/1000.0+1                                      MM38  590
      NX1 = (RP1-RP5)/2000.0+0.5                                        MM38  600
      NR = NX5+NX1                                                      MM38  610
      WRITE (6,40) NSIM                                                 MM38  620
      WRITE (6,50)                                                      MM38  630
      WRITE (6,60)                                                      MM38  640
      WRITE (6,70)                                                      MM38  650
      WRITE (6,160)                                                     MM38  660
      WRITE (6,80)                                                      MM38  670
      WRITE (6,90)                                                      MM38  680
C                                                                       MM38  690
C                                                                       MM38  700
      READ (5,20) THETA(1),THETA(2)                                     MM38  710
      READ (5,20) ACTIV(1),ACTIV(2)                                     MM38  720
      READ (5,20) L(1),L(2)                                             MM38  730
      READ (5,30) V,VMAX,TRNRTE,ACC                                     MM38  740
      WRITE (6,100) V,VMAX,ACC,TRNRTE                                   MM38  750
      WRITE (6,110)                                                     MM38  760
      V1 = V*CFS                                                        MM38  770
      V1MAX = VMAX*CFS                                                  MM38  780
      TS = 90.0/TRNRTE                                                  MM38  790
      IF (ACC.EQ.0.0) GO TO 170                                         MM38  800
      ACT = (V1MAX-V1)/ACC                                              MM38  810
      GO TO 180                                                         MM38  820
  170 ACT = 0.0                                                         MM38  830
  180 DEL = DETDEL+TRNDEL                                               MM38  840
      WDRAD = WDIREC*RADIAN                                             MM38  850
      YWIND = WSPEED*COS(WDRAD)                                         MM38  860
C                                                                       MM38  870
CC                                                                      MM38  880
CC    ************************************************************      MM38  890
CC    *                                                          *      MM38  900
CC    *   GENERATION OF                                          *      MM38  910
C     *                                                          *      MM38  920
```

```
C      *            - TARGET ASPECT-ANGLE                                  *      MM38 930
CC     *            - MISSILE LAUNCH-RANGE                                 *      MM38 940
CC     *            - SENSOR-DEVIATION                                     *      MM38 950
CC     *            - POA-SHIFT                                            *      MM38 960
CC     *            - TARGET-DATA (COURSE,SPEED,TURNRADIUS)                *      MM38 970
CC     *            - TRUE MISSILE SPEED W/R TO WIND EFFECTS               *      MM38 980
CC     *            - TARGET REACTION-DELAYTIME                            *      MM38 990
CC     *            - MISSILE NAVIGATION-ERROR                             *      MM381000
CC     *                                                                   *      MM381010
CC     *********************************************************************      MM381020
CCC                                                                               MM381030
CC                                                                                MM381040
C                                                                                 MM381050
      DO 600 K=7,NROT                                                             MM381060
      DEG1(K) = (K-1)*30.0                                                        MM381070
      A1(K) = DEG1(K)*RADIAN                                                      MM381080
      BETA1(K) = (DEG1(K)+180.0)-360.0                                            MM381090
      EPS1 = ABS(180.0-DEG1(K))                                                   MM381100
      E1 = EPS1*RADIAN                                                            MM381110
C                                                                                 MM381120
C                                                                                 MM381130
      DO 580 KK=1,2                                                               MM381140
C                                                                                 MM381150
C                                                                                 MM381160
      DO 570 I=1,NR                                                               MM381170
      IF (I.GT.NX5) GO TO 190                                                     MM381180
      RANGE1(I) = (I+13)*1000.0                                                   MM381190
      GO TO 200                                                                   MM381200
  190 RANGE1(I) = I*2000.0                                                        MM381210
  200 RX1(I) = RANGE1(I)-14000.0                                                  MM381220
      XRNG1 = RANGE1(I)*SIN(A1(K))                                                MM381230
      YRNG1 = RANGE1(I)*COS(A1(K))                                                MM381240
      SB = SIGBL*RADIAN                                                           MM381250
      SBT1 = RANGE1(I)*TAN(SB)                                                    MM381260
      SRT1 = SIGRL                                                                MM381270
      IF (RANGE1(I).GT.RNG5) GO TO 210                                            MM381280
      TREAC = DEL                                                                 MM381290
      GO TO 220                                                                   MM381300
  210 TREAC = ((RANGE1(I)-RNG5)/VMISS)+DEL                                        MM381310
  220 Y = V1*TREAC                                                                MM381320
C                                                                                 MM381330
C                                                                                 MM381340
      TY = (RANGE1(I)-ACTIV(1)+(TDEL(1)-TLAUN)*VMISS)/VMISS                       MM381350
      VY = V1+ACC*TY                                                              MM381360
      VYFIN = AMIN1(V1MAX,VY)                                                     MM381370
      VYAVG = (V1+VYFIN)/2.0                                                      MM381380
      IF (ACT.GT.TY) GO TO 230                                                    MM381390
      YMAX = VYAVG*ACT+(TY-ACT)*VYFIN                                             MM381400
```

```
      GO TO 240                                                          MM381410
  230 YMAX = VYAVG*TY                                                    MM381420
  240 Q = YMAX-L(1)+3.0*SIGRL                                            MM381430
      IF (IFLAGP.EQ.0) GO TO 250                                         MM381440
      IF (Q.LT.0.0) GO TO 250                                            MM381450
C                                                                        MM381460
CC                                                                       MM381470
C     ***********                                                        MM381480
      PCA = Q                                                            MM381490
      GO TO 260                                                          MM381500
  250 PCA = 0.0                                                          MM381510
C     ***********                                                        MM381520
C                                                                        MM381530
  260 RPCA1 = SQRT(POA**2+(RANGE1(I))**2-2.0*POA*RANGE1(I)*COS(E1))      MM381540
      IF (POA.GT.0.0) GO TO 270                                          MM381550
      Z1 = 0.0                                                           MM381560
      GO TO 280                                                          MM381570
  270 Z1 = ARSIN((POA*SIN(E1))/RPOA1)                                    MM381580
  280 IF (DEG1(K).GT.180.0) GO TO 290                                    MM381590
      ZA1 = A1(K)-Z1                                                     MM381600
      GO TO 300                                                          MM381610
  290 ZA1 = A1(K)+Z1                                                     MM381620
  300 ZETA1 = ZA1*CF                                                     MM381630
C                                                                        MM381640
C                                                                        MM381650
      DO 310 KA=1,NA                                                     MM381660
C                                                                        MM381670
      DO 310 KT=1,NT                                                     MM381680
C                                                                        MM381690
      DO 310 KL=1,NL                                                     MM381700
      PC(I,KA,KT,KL) = 0.0                                               MM381710
  310 P(I,KA,KT,KL) = 0.0                                                MM381720
C                                                                        MM381730
CC                                                                       MM381740
CC                                                                       MM381750
C                                                                        MM381760
      DO 550 ISIM=1,NSIM                                                 MM381770
C                                                                        MM381780
C                                                                        MM381790
      CALL NORMAL (NCOURS,ZCOURS,1)                                      MM381800
      TRUCRS = ESTCRS+ZCOURS*SIGCL                                       MM381810
      PSI = TRUCRS*RADIAN                                                MM381820
C                                                                        MM381830
C                                                                        MM381840
      CALL NORMAL (NSPD,ZTSPC,1)                                         MM381850
      VV = V1+ZTSPC*SIGSL                                                MM381860
      IF (ACC.EQ.0.0) GO TO 320                                          MM381870
      ACCTIM = (V1MAX-VV)/ACC                                            MM381880
```

```
      GC TO 330                                                          MM381850
  320 ACCTIM = 0.0                                                       MM381900
  330 VS = VV+ACC*T9                                                     MM381910
      VSFIN = AMIN1(V1MAX,V9)                                            MM381920
      VSAVG = (VV+V9FIN)/2.0                                             MM381930
      IF (ACCTIM.GT.T9) GO TO 340                                        MM381940
      YS = V9AVG*ACCTIM+(T9-ACCTIM)*VSFIN                                MM381950
      GC TO 350                                                          MM381960
  340 YS = V9AVG*T9                                                      MM381970
  350 RADIUS = 2.0*Y9/PI                                                 MM381980
C                                                                        MM381990
C                                                                        MM382000
      CALL NORMAL (MSPD1,ZMSPD1,1)                                       MM382010
      VMISS1 = VMISS+ZMSPD1*SIGVM                                        MM382020
      XMISS1 = VMISS1*SIN(ZA1)                                           MM382030
      YMISS1 = VMISS1*COS(ZA1)                                           MM382040
      YMW1 = YMISS1+YWIND                                                MM382050
      VEXOC1 = SQRT(XMISS1**2+YMW1**2)                                   MM382060
C                                                                        MM382070
CC                                                                       MM382080
      CALL NORMAL (NDELAY,ZDELAY,1)                                      MM382090
      DELAY = DEL+ZDELAY*SIGDEL                                          MM382100
C                                                                        MM382110
CCCC                                                                     MM382120
CCCCC ***************************************************************  MM382130
CCCCC *                                                             *  MM382140
CCCCC *   ** GENERATION OF THE TRUE TARGET-POSITION AT LAUNCH **    *  MM382150
CCCCC *                                                             *  MM382160
CCCCC ***************************************************************  MM382170
CCCC                                                                     MM382180
C                                                                        MM382190
      CALL NORMAL (NDET1,ZDET1,2)                                        MM382200
      SDETB1 = ZDET1(1)*SBT1                                             MM382210
      SDETR1 = ZDET1(2)*SRT1                                             MM382220
      XD1 = SDETB1*COS(A1(K))+SDETR1*SIN(A1(K))                          MM382230
      YD1 = (-1)*SDETB1*SIN(A1(K))+SDETR1*COS(A1(K))                     MM382240
      XPOS1 = XRNG1+XD1                                                  MM382250
      YPOS1 = YRNG1+YD1                                                  MM382260
      RPOS1 = SQRT(XPOS1**2+YPOS1**2)                                    MM382270
C                                                                        MM382280
      IF (RPOS1.GT.RNG5) GO TO 360                                       MM382290
      REACT = DELAY                                                      MM382300
      GC TO 370                                                          MM382310
  360 REACT = ((RPOS1-RNG5)/VEXOC1)+DELAY                                MM382320
  370 YY = VV*REACT                                                      MM382330
C                                                                        MM382340
CC                                                                       MM382350
C     ***************************************************************  MM382360
```

```
C      *                                                              *      MM382370
C      *   ** GENERATION OF TRUE MISSILE-POSITION AT LOCK-ON **       *      MM382380
C      *                                                              *      MM382390
C      ****************************************************************      MM382400
C                                                                             MM382410
C                                                                             MM382420
C      DO 540 KA=1,NA                                                         MM382430
C                                                                             MM382440
C                                                                             MM382450
C      DO 530 KT=1,NT                                                         MM382460
C                                                                             MM382470
       RLAUN1 = (RPOA1-ACTIV(KA))+(TDEL(KT)-TLAUN)*VEXOC1                     MM382480
       XLAUN1 = RLAUN1*SIN(ZA1)                                               MM382490
       YLAUN1 = RLAUN1*COS(ZA1)                                               MM382500
       TFLIT1 = RLAUN1/VEXOC1                                                 MM382510
       TLOCK1 = TFLIT1+TLAUN                                                  MM382520
C                                                                             MM382530
C      CALL NORMAL (NLOCK,ZLOCK,2)                                            MM382540
       SLOKB1 = 1.62*TLOCK1*ZLOCK(1)                                          MM382550
       SLOKR1 = SLOKB1                                                        MM382560
       XL1 = SLOKB1*COS(ZA1)+SLOKR1*SIN(ZA1)                                  MM382570
       YL1 = (-1)*SLOKB1*SIN(ZA1)+SLOKR1*COS(ZA1)                             MM382580
       XLOCK1 = XLAUN1+XL1                                                    MM382590
       YLOCK1 = YLAUN1+YL1                                                    MM382600
       RLOCK1 = SQRT(XLOCK1**2+YLOCK1**2)                                     MM382610
C                                                                             MM382620
C      ****************************************************************      MM382630
C      *                                                              *      MM382640
C      *                ** DECISION FOR FINAL COURSE **               *      MM382650
C      *   ** GENERATION OF TRUE TARGET-POSITION AT LOCK-ON **        *      MM382660
C      *                                                              *      MM382670
C      ****************************************************************      MM382680
C                                                                             MM382690
       TIME1 = TLOCK1-REACT                                                   MM382700
       IF (TIME1.LT.0.0) TIME1=0.0                                            MM382710
       VV1 = VV+ACC*TIME1                                                     MM382720
       VV1FIN = AMIN1(V1MAX,VV1)                                              MM382730
       VV1AVG = (VV+VV1FIN)/2.0                                               MM382740
       IF (ACCTIM.GT.TIME1) GO TO 380                                         MM382750
       YR1 = VV1AVG*ACCTIM+(TIME1-ACCTIM)*VV1FIN                              MM382760
       GO TO 390                                                              MM382770
  380  YR1 = VV1AVG*TIME1                                                     MM382780
C                                                                             MM382790
```

```
C                                                                       MM382850
  390 CALL RANDOM (NTIME1,UTURN1,1)                                     MM382860
      IF (UTURN1.GT.0.9999) UTURN1=0.9999                               MM382870
      IF (T9.GT.TIME1) GO TO 400                                        MM382880
      TT1 = UTURN1*T9                                                   MM382890
      GO TO 410                                                         MM382900
  400 TT1 = UTURN1*TIME1                                                MM382910
  410 DELTA1 = TT1*TRNRTE                                               MM382920
      D1 = DELTA1*RADIAN                                                MM382930
C                                                                       MM382940
      TG1X1 = RADIUS*(1.0-COS(D1))+(YR1-RADIUS*D1)*SIN(D1)              MM382950
      TG1Y1 = YY+RADIUS*SIN(D1)+(YR1-RADIUS*D1)*COS(D1)                 MM382960
      TG1X2 = (-1)*TG1X1                                                MM382970
      TG1Y2 = TG1Y1                                                     MM382980
C                                                                       MM382990
      TG1X1R = TG1X1*COS(PSI)+TG1Y1*SIN(PSI)                            MM383000
      TG1Y1R = (-1)*TG1X1*SIN(PSI)+TG1Y1*COS(PSI)                       MM383010
      TG1X2R = TG1X2*COS(PSI)+TG1Y2*SIN(PSI)                            MM383020
      TG1Y2R = (-1)*TG1X2*SIN(PSI)+TG1Y2*COS(PSI)                       MM383030
C                                                                       MM383040
      TG1LX1 = XPOS1+TG1X1R                                             MM383050
      TG1LY1 = YPOS1+TG1Y1R                                             MM383060
      TG1LX2 = XPOS1+TG1X2R                                             MM383070
      TG1LY2 = YPOS1+TG1Y2R                                             MM383080
C                                                                       MM383090
CCC                                                                     MM383100
CCC   ***************************************************************   MM383110
CCC   *                                                             *   MM383120
CCC   *                  ** DECISION FOR TURN-DIRECTION **          *   MM383130
CCC   *                                                             *   MM383140
CCC   ***************************************************************   MM383150
CCC                                                                     MM383160
C                                                                       MM383170
      CALL RANDOM (NTURN1,UPOS1,1)                                      MM383180
      IF (UPOS1.GT.0.9999) UPOS1=0.9999                                 MM383190
      IF (UPOS1.GT.0.5000) GO TO 420                                    MM383200
      SIM1X = TG1LX1                                                    MM383210
      SIM1Y = TG1LY1                                                    MM383220
      GO TO 430                                                         MM383230
  420 SIM1X = TG1LX2                                                    MM383240
      SIM1Y = TG1LY2                                                    MM383250
C                                                                       MM383260
CCC                                                                     MM383270
CCC   ***************************************************************   MM383280
CCC   *                                                             *   MM383290
CCC   *              ** TEST FOR TARGET-ACQUISITION **              *   MM383300
CCC   *                                                             *   MM383310
C     ***************************************************************   MM383320
```

```
C                                                                               MM383330
C                                                                               MM383340
  430 TAL1(KT) = ZETA1-THETA(KT)                                                MM383350
      TAL2(KT) = ZETA1+THETA(KT)                                                MM383360
      XTEST1 = SIM1X-XLOCK1                                                     MM383370
      YTEST1 = SIM1Y-YLOCK1                                                     MM383380
      R1 = SQRT(XTEST1**2+YTEST1**2)                                            MM383390
      G1 = ARSIN(XTEST1/R1)                                                     MM383400
C                                                                               MM383410
      IF (DEG1(K).LT.090.0) GO TO 450                                           MM383420
      IF (DEG1(K).EQ.090.0) GO TO 440                                           MM383430
      IF (DEG1(K).LT.270.0) GO TO 470                                           MM383440
      IF (DEG1(K).EQ.270.0) GO TO 460                                           MM383450
      IF (DEG1(K).LE.360.0) GO TO 480                                           MM383460
C                                                                               MM383470
  440 IF (SDETB1.GE.0.0) GO TO 470                                              MM383480
  450 GAMMA1 = G1*CF                                                            MM383490
      GO TO 490                                                                 MM383500
  460 IF (SDETB1.GE.0.0) GO TO 480                                              MM383510
  470 GAMMA1 = (-1)*G1*CF+180.0                                                 MM383520
      GO TO 490                                                                 MM383530
  480 GAMMA1 = G1*CF+360.0                                                      MM383540
  490 IF ((GAMMA1.GT.TAU1(KT)).AND.(GAMMA1.LT.TAU2(KT))) GO TO 500              MM383550
      GO TO 530                                                                 MM383560
C                                                                               MM383570
C                                                                               MM383580
  500 DO 520 KL=1,NL                                                            MM383590
      RTEST1(KL) = ACTIV(KA)-(TDEL(KT)-TLAUN)*VEXCC1+L(KL)                      MM383600
      RTEST2(KL) = ACTIV(KA)-(TDEL(KT)-TLAUN)*VEXC+1+L(KL)                      MM383610
      IF ((R1.LT.RTEST1(KL)).AND.(R1.GT.RTEST2(KL))) GO TO 510                  MM383620
      GO TO 520                                                                 MM383630
  510 P(I,KA,KT,KL) = P(I,KA,KT,KL)+1.0                                         MM383640
C                                                                               MM383650
  520 CONTINUE                                                                  MM383660
C                                                                               MM383670
C                                                                               MM383680
  530 CONTINUE                                                                  MM383690
C                                                                               MM383700
C                                                                               MM383710
  540 CONTINUE                                                                  MM383720
C                                                                               MM383730
C                                                                               MM383740
  550 CONTINUE                                                                  MM383750
C                                                                               MM383760
C                                                                               MM383770
C                                                                               MM383780
      DO 560 KA=1,NA                                                            MM383790
C                                                                               MM383800
```

```
      DO 560 KT=1,NT                                                    MM383810
C                                                                       MM383820
      DO 560 KL=1,NL                                                    MM383830
C                                                                       MM383840
  560 PX(KK,I,KA,KT,KL) = P(I,KA,KT,KL)/REAL                           MM383850
C                                                                       MM383860
C                                                                       MM383870
  570 CONTINUE                                                          MM383880
C                                                                       MM383890
C                                                                       MM383900
  580 CONTINUE                                                          MM383910
C                                                                       MM383920
CC                                                                      MM383930
C                                                                       MM383940
      DO 590 I=1,NR                                                     MM383950
C                                                                       MM383960
      DO 590 KA=1,NA                                                    MM383970
C                                                                       MM383980
      DO 590 KT=1,NT                                                    MM383990
C                                                                       MM384000
      DO 590 KL=1,NL                                                    MM384010
  590 PD(I,KA,KT,KL) = (PX(1,I,KA,KT,KL)+PX(2,I,KA,KT,KL))/2.0          MM384020
C                                                                       MM384030
CC                                                                      MM384040
CC    ************************************************************      MM384050
CC    *                                                          *      MM384060
CC    *                                                          *      MM384070
CC    *               **          RESULTS          **            *      MM384080
CC    *                                                          *      MM384090
CC    ************************************************************      MM384100
CC                                                                      MM384110
C                                                                       MM384120
      WRITE (6,120) BETA1(K),DEG1(K)                                    MM384130
      WRITE (6,150)                                                     MM384140
      WRITE (6,130)                                                     MM384150
      WRITE (6,140) (RANGE1(I),PD(I,1,1,1),PD(I,1,1,2),PD(I,1,2,1),PD(I,MM384160
     1 1,2,2),I=1,NR)                                                   MM384170
  600 CONTINUE                                                          MM384180
C                                                                       MM384190
C                                                                       MM384200
      STOP                                                              MM384210
      END                                                               MM384220
```

# APPENDIX D

## SIMULATION-MODEL MM38-OTH

```
      DIMENSICN THETA(2), ACTIV(2), L(2), TDEL(2)                       MM38   10
      DIMENSION RANGE1(10), A1(10), ALFA1(10)                           MM38   20
      CIMENSICN AA1(10), RLPEP1(10), BEPTG1(10)                         MM38   30
      CIMENSICN TAU1(2), TAU2(2), RTEST1(2), RTEST2(2)                  MM38   40
      CIMENSICN P(4,2,2,2,2), PX(4,2,2,2,2), PD(4,2,2,2)                MM38   50
      CIMENSICN SIGBE(6)                                                MM38   60
      CIMENSICN ZDET1(2), ZPOS1(2), ZLCCK(2)                            MM38   70
      REAL L,MISRED                                                     MM38   80
C                                                                       MM38   90
C                                                                       MM38  100
      CATA NSENSD,NTGROT,NEXROT,NR,NEPTG1/1,3,4,3,4/                    MM38  110
      CATA NA,NT,NL/2,2,2/                                              MM38  120
      CATA RELAY,DELEVA,MISRED,TRNDEL/10.0,10.0,12.0,10.0/              MM38  130
      CATA TDEL/5.90,7.90/                                              MM38  140
      CATA TLAUN/2.5/                                                   MM38  150
      CATA RLEMIN/10000.0/                                              MM38  160
      DATA PI,RADIAN,CF/3.141593,0.017453,57.295779/                    MM38  170
      CATA CFS/0.51444/                                                 MM38  180
      CATA SIGVM,SIGDEL/1.5,1.5/                                        MM38  190
      CATA SIGCE,SIGSE/5.0,1.5/                                         MM38  200
      CATA SIGBL,SIGRL/0.14,10.0/                                       MM38  210
      CATA SIGRE/30.0/                                                  MM38  220
      CATA SIGBE/1.0,2.0,3.0/                                           MM38  230
      CATA VMISS/315.0/                                                 MM38  240
      CATA WSPEED,WDIREC/0.0,315.0/                                     MM38  250
C                                                                       MM38  260
C                                                                       MM38  270
   20 FCRMAT (2F10.2)                                                   MM38  280
   30 FCRMAT (3F10.2,F10.4)                                             MM38  290
   40 FCRMAT ('1','SIMULATION - RUNS  - ',I3,' -',//)                   MM38  300
   50 FCRMAT ('0',5X,'** O T H - TARGETING ** (32C00 - 40000 METERS)'//)MM38  310
   60 FCRMAT ('C',15X,'FIRST LETTER REFERS TO ACTIVATION-DISTANCE',/)   MM38  320
   7C FCRMAT ('0',15X,'SECOND LETTER REFERS TO SEARCH-ANGLE',/)         MM38  330
   8C FCRMAT ('0',15X,'THIRD LETTER REFERS TO SEARCH-DEPTH',/)          MM38  340
   9C FCRMAT ('0',T47,'** TARGET - DDG KRIVAK-CLASS **',//)             MM38  350
  100 FCRMAT ('0',9X,'TARGET COURSE - 180 DEGREES -',//)                MM38  360
  11C FCRMAT ('0',15X,'V1 (KN):',F5.1,5X,'VMAX (KN):',F5.1,5X,'ACCELERATMM38  370
     1ICN (M/SEC**2):',F6.3,5X,'TURN-RATE (DEG/SEC):',F3.1,//)          MM38  380
  120 FCRMAT ('0',15X,'* DATA - COURSE,SPEED,BEARING,RANGE - ARE ESTIMATMM38  390
     1ES.WIND EFFECTS ARE TAKEN INTO ACCCUNT. *',//)                    MM38  400
  130 FCRMAT ('0',9X,'LAUNCH-PLATFORM CATA',//,15X,'SENSCR BEARING ERRORMM38  410
     1 (1 SIGMA) :',F7.4,' DEGREES',//,15X,'SENSCR RANGE ERROR (1 SIGMA)MM38  420
     2 :',F4.1,' METERS',//)                                            MM38  430
  140 FCRMAT ('0',9X,'EXTENDED PLATFORM DATA',//,15X,'SENSCR BEARING ERRMM38  440
```

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     1OR (1 SIGMA) :',F4.1,' DEGREES',//,15X,'SENSOR RANGE ERROR (1 SIGMMM38  450
     2A) :',F5.1,' METERS',//)                                          MM38  460
  15C FORMAT ('0',15X,'TARGET-DATA ACCURACIES (3 SIGMA) BY EXTENDED PLATMM38  470
     1FORM',//,20X,'COURSE : 10.0 DEGREES',/,20X,'SPEED  :  3.0 KN',//) MM38  480
  160 FORMAT ('0',15X,'COURSE LAUNCH-PLATFORM 360 DEGREES',//,16X,'LOCATMM38  490
     1ION OF EXTENDED PLATFORM FROM -15 TO +15 DEGREES',//)             MM38  500
  17C FORMAT ('1','** ASPECT - ANGLE :',F7.1,' **',5X,'BEARING:',F6.1//)MM38  510
  18C FORMAT ('0',5X,'BEARING LAUNCH-PLATFORM - EXTENDED PLATFORM :',F6.MM38  520
     11,' DEGREES',//)                                                  MM38  530
  190 FORMAT ('0',5X,'RANGE LAUNCH-PLATFORM - TARGET :',F8.1,' METERS',/MM38  540
     1/)                                                                MM38  550
  200 FORMAT ('0',5X,'SHIFT OF THE POINT-OF-AIM BY',F6.1,' METERS IN DIRMM38  560
     1ECTION 180 DEGREES',//)                                           MM38  570
  210 FORMAT ('0',5X,'* MISSILE LAUNCHED IN',F6.1,' DEGREES AT A RANGE CMM38  580
     1F',F8.1,' METERS',//)                                             MM38  590
  220 FORMAT ('0',10X,'ACTIVATION - DISTANCE: K',///,7X,'REPTG',T17,'BEPMM38  600
     1TG',T25,'RLPEP',T38,'KKK',T46,'KKG',T56,'KGK',T64,'KGG',//)       MM38  610
  230 FORMAT ('0',10X,'ACTIVATION - DISTANCE: G',///,7X,'REPTG',T17,'BEPMM38  620
     1TG',T25,'RLPEP',T38,'GKK',T46,'GKG',T56,'GGK',T64,'GGG',//)       MM38  630
  240 FORMAT (' ',5X,F7.1,T17,F5.1,T24,F7.1,T37,F6.4,T45,F6.4,T55,F6.4,TMM38  640
     163,F6.4)                                                          MM38  650
  25C FORMAT (//)                                                       MM38  660
C                                                                       MM38  670
CC                                                                      MM38  680
      CALL OVFLOW                                                       MM38  690
      NCCURS = 412089                                                   MM38  700
      NSFD = 2301473                                                    MM38  710
      NSPD1 = 7683021                                                   MM38  720
      NDELAY = 753021                                                   MM38  730
      NDET1 = 3658709                                                   MM38  740
      NLOCK = 4321078                                                   MM38  750
      NTIME1 = 7852014                                                  MM38  760
      NTURN1 = 1425836                                                  MM38  770
      ESTCRS = 0.0                                                      MM38  780
      NSIM = 400                                                        MM38  790
      REAL = NSIM                                                       MM38  800
      IFLAGP = 0                                                        MM38  810
C                                                                       MM38  820
CC                                                                      MM38  830
      READ (5,20) THETA(1),THETA(2)                                     MM38  840
      READ (5,20) ACTIV(1),ACTIV(2)                                     MM38  850
      READ (5,20) L(1),L(2)                                             MM38  860
      READ (5,30) V,VMAX,TRNRTE,ACC                                     MM38  870
C                                                                       MM38  880
      V1 = V*CFS                                                        MM38  890
      V1MAX = VMAX*CFS                                                  MM38  900
      TS = 90.0/TRNRTE                                                  MM38  910
      WCRAD = WDIREC*RADIAN                                             MM38  920
```

```
      YWIND = WSPEED*COS(WDRAD)                                          MM38 930
      IF (ACC.EQ.0.0) GO TO 260                                          MM38 940
      ACT = (V1MAX-V1)/ACC                                               MM38 950
      GO TO 270                                                          MM38 960
  260 ACT = 0.0                                                          MM38 970
  270 DEL = RELAY+DELEVA+MISRED+TRNDEL                                   MM38 980
C                                                                        MM38 990
CC                                                                       MM381000
C                                                                        MM381010
      DO 680 KS=1,NSENSD                                                 MM381020
      SBE = SIGBE(KS)*RADIAN                                             MM381030
C                                                                        MM381040
      WRITE (6,40) NSIM                                                  MM381050
      WRITE (6,50)                                                       MM381060
      WRITE (6,60)                                                       MM381070
      WRITE (6,70)                                                       MM381080
      WRITE (6,80)                                                       MM381090
      WRITE (6,90)                                                       MM381100
      WRITE (6,100)                                                      MM381110
      WRITE (6,110) V,VMAX,ACC,TRNRTE                                    MM381120
      WRITE (6,120)                                                      MM381130
      WRITE (6,130) SIGBL,SIGRL                                          MM381140
      WRITE (6,140) SIGBE(KS),SIGRE                                      MM381150
      WRITE (6,150)                                                      MM381160
      WRITE (6,160)                                                      MM381170
C                                                                        MM381180
CC                                                                       MM381190
CCC   ****************************************************************   MM381200
CCC   *                                                              *   MM381210
CCC   *        ** GENERATION OF ESTIMATED TARGET POSITION **         *   MM381220
CCC   *                                                              *   MM381230
CCC   *        ** GENERATION OF EXTENDED PLATFORM POSITION **        *   MM381240
CCC   *                                                              *   MM381250
CCC   ****************************************************************   MM381260
CCC                                                                      MM381270
C                                                                        MM381280
C                                                                        MM381290
      DO 670 M=1,NTGROT                                                  MM381300
      DEG1 = (M+9)*30.0                                                  MM381310
      ETA1 = 360.0-DEG1                                                  MM381320
      ASP1 = (-1)*ETA1                                                   MM381330
      DG1 = DEG1*RADIAN                                                  MM381340
      ET1 = ETA1*RADIAN                                                  MM381350
C                                                                        MM381360
CC                                                                       MM381370
C                                                                        MM381380
      DO 660 K=1,NEXROT                                                  MM381390
      A1(K) = K*5.0                                                      MM381400
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```
      A1RAD = A1(K)*RADIAN                                                  MM381410
      ALFA1(K) = DEG1+A1(K)                                                 MM381420
      IF (ALFA1(K).GT.360.0) ALFA1(K)=ALFA1(K)-360.0                        MM381430
C                                                                           MM381440
C                                                                           MM381450
C                                                                           MM381460
      DO 650 I=1,NR                                                         MM381470
      RANGE1(I) = (I+7)*4000.0                                              MM381480
      RLPTG1 = RANGE1(I)                                                    MM381490
      TREAC = DEL                                                           MM381500
      Y = V1*TREAC                                                          MM381510
C                                                                           MM381520
      XRNG1 = RANGE1(I)*SIN(DG1)                                            MM381530
      YRNG1 = RANGE1(I)*COS(DG1)                                            MM381540
C                                                                           MM381550
C                                                                           MM381560
      DO 640 KK=1,NEPTG1                                                    MM381570
C                                                                           MM381580
C                                                                           MM381590
      DO 620 KX=1,2                                                         MM381600
C                                                                           MM381610
      IF (K.EQ.1) GO TO 280                                                 MM381620
      IF (K.EQ.2) GO TO 280                                                 MM381630
      IF (K.EQ.3) GO TO 290                                                 MM381640
      IF (K.EQ.4) GO TO 300                                                 MM381650
C                                                                           MM381660
  280 SAFETY = 10000.0                                                      MM381670
      GO TO 310                                                             MM381680
  290 SAFETY = 12000.0                                                      MM381690
      RLEMIN = 12000.0                                                      MM381700
      GO TO 310                                                             MM381710
  300 SAFETY = 14000.0                                                      MM381720
      RLEMIN = 14000.0                                                      MM381730
C                                                                           MM381740
  310 CCRAD = PI-ARSIN((RANGE1(I)*SIN(A1RAD))/SAFETY)                       MM381750
      BBRAD = PI-(A1RAD+CCRAD)                                              MM381760
      RLEMAX = (RANGE1(I)*SIN(BBRAD))/SIN(CCRAD)                            MM381770
      DIFF = RLEMAX-RLEMIN                                                  MM381780
      INCRNG = DIFF/3000.0                                                  MM381790
C                                                                           MM381800
      IF (K.EQ.3) RLEMIN = 12000.0                                          MM381810
C                                                                           MM381820
      AA1(KK) = RLEMIN+(KK-1)*INCRNG*1000.0                                 MM381830
      C1RAD = PI-ARSIN((RANGE1(I)*SIN(A1RAD))/AA1(KK))                      MM381840
      C1 = C1RAD*CF                                                         MM381850
      B1RAD = PI-(A1RAD+C1RAD)                                              MM381860
      B1 = B1RAD*CF                                                         MM381870
      RLPEP1(KK) = (RANGE1(I)*SIN(B1RAD))/SIN(C1RAD)                        MM381880
```

```
      REPTG1 = AA1(KK)                                                  MM381890
      BEPTG1(KK) = ALFA1(K)-(180.0-C1)                                  MM381900
C                                                                       MM381910
C                                                                       MM381920
      SDRL = SIGRL                                                      MM381930
      SBL = SIGBL*RADIAN                                                MM381940
      SDBL = RLPEP1(KK)*TAN(SBL)                                        MM381950
C                                                                       MM381960
      SDRE1 = SIGRE                                                     MM381970
      SDBE1 = REPTG1*TAN(SBE)                                           MM381980
C                                                                       MM381990
      SDEVB1 = SQRT(SDBL**2+SDBE1**2)                                   MM382000
      SDEVR1 = SQRT(SDRL**2+SDRE1**2)                                   MM382010
C                                                                       MM382020
      TY = (RANGE1(I)-ACTIV(1)+(TDEL(1)-TLAUN)*VMISS)/VMISS             MM382030
      VY = V1+ACC*TY                                                    MM382040
      VYFIN = AMIN1(V1MAX,VY)                                           MM382050
      VYAVG = (V1+VYFIN)/2.0                                            MM382060
      IF (ACT.GT.TY) GO TO 320                                          MM382070
      YMAX = VYAVG*ACT+(TY-ACT)*VYFIN                                   MM382080
      GO TO 330                                                         MM382090
  320 YMAX = VYAVG*TY                                                   MM382100
  330 Q = YMAX-L(1)+3.0*SDEVR1                                          MM382110
      IF (IFLAGP.EQ.0) GO TO 340                                        MM382120
      IF (Q.LT.0.0) GO TO 340                                           MM382130
C                                                                       MM382140
CCCCC                                                                   MM382150
CCCCC ****************************************************************MM382160
CCCCC *                                                              *MM382170
CCCCC *  ** GENERATION OF ESTIMATED MISSILE LOCK-ON-POSITION **      *MM382180
CCCCC *                  W/R TO A SHIFT OF THE PCA                   *MM382190
C     ********************                                            *MM382200
      PCA = Q                                                           MM382210
      GO TO 350                                                         MM382220
  340 PCA = 0.0                                                         MM382230
C     ********************                                            *MM382240
CCCCC *                                                              *MM382250
CCCCC ****************************************************************MM382260
CCCCC                                                                   MM382270
C                                                                       MM382280
  350 RPOA1 = SQRT(POA**2+RLPTG1**2-2.0*POA*RLPTG1*COS(ET1))            MM382290
      IF (POA.GT.0.0) GO TO 360                                         MM382300
      Z1 = 0.0                                                          MM382310
      GO TO 370                                                         MM382320
  360 Z1 = ARSIN((POA*SIN(ET1))/RPOA1)                                  MM382330
  370 IF (DEG1.GE.360.0) GO TO 380                                      MM382340
      ZA1 = DG1-Z1                                                      MM382350
      GO TO 390                                                         MM382360
```

```
  380 ZA1 = DG1+Z1                                                      MM382370
  390 ZETA1 = ZA1*CF                                                    MM382380
C                                                                       MM382390
C                                                                       MM382400
      DO 400 KA=1,NA                                                    MM382410
C                                                                       MM382420
      DO 400 KT=1,NT                                                    MM382430
C                                                                       MM382440
      DO 400 KL=1,NL                                                    MM382450
C                                                                       MM382460
  400 P(KK,KX,KA,KT,KL) = 0.0                                           MM382470
C                                                                       MM382480
C                                                                       MM382490
C                                                                       MM382500
C                                                                       MM382510
      DO 600 ISIM=1,NSIM                                                MM382520
C                                                                       MM382530
      CALL NORMAL (NCOURS,ZCOURS,1)                                     MM382540
      TRUCRS = ESTCRS+ZCOURS*SIGCE                                      MM382550
      CCR360 = TRUCRS                                                   MM382560
      CCR180 = TRUCRS+180.0                                             MM382570
      PSI = CCR180*RADIAN                                               MM382580
C                                                                       MM382590
C                                                                       MM382600
      VV = V1+ZTSPD*SIGSE                                               MM382610
      ACCTIM = (V1MAX-VV)/ACC                                           MM382620
      V9 = VV+ACC*T9                                                    MM382630
      V9FIN = AMIN1(V1MAX,V9)                                           MM382640
      V9AVG = (VV+V9FIN)/2.0                                            MM382650
      IF (ACCTIM.GT.T9) GO TO 410                                       MM382660
      Y9 = V9AVG*ACCTIM+(T9-ACCTIM)*V9FIN                               MM382670
      GO TO 420                                                         MM382680
  410 Y9 = V9AVG*T9                                                     MM382690
  420 RADIUS = 2.0*Y9/PI                                                MM382700
C                                                                       MM382710
C                                                                       MM382720
      CALL NORMAL (MSPD1,ZMSPD1,1)                                      MM382730
      VMISS1 = VMISS+ZMSPD1*SIGVM                                       MM382740
      XMISS1 = VMISS1*SIN(ZA1)                                          MM382750
      YMISS1 = VMISS1*COS(ZA1)                                          MM382760
      YMW1 = YMISS1+YWIND                                               MM382770
      VEXOC1 = SQRT(XMISS1**2+YMW1**2)                                  MM382780
C                                                                       MM382790
C                                                                       MM382800
      CALL NORMAL (NDELAY,ZDELAY,1)                                     MM382810
      DELAY = DEL+ZDELAY*SIGDEL                                         MM382820
C                                                                       MM382830
C                                                                       MM382840
```

```
C      ************************************************************      MM382850
CC     *                                                          *      MM382860
CCC    *    ** GENERATION OF THE TRUE TARGET-POSITION AT LAUNCH **   *      MM382870
CCCC   *                                                          *      MM382880
CCCCC  ************************************************************      MM382890
CCCCCC                                                                    MM382900
C                                                                         MM382910
       CALL NORMAL (NDET1,ZDET1,2)                                        MM382920
       SDETB1 = ZDET1(1)*SDEVB1                                           MM382930
       SDETR1 = ZDET1(2)*SDEVR1                                           MM382940
       XD1 = SDETB1*COS(DG1)+SDETR1*SIN(DG1)                              MM382950
       YD1 = (-1)*SDETB1*SIN(DG1)+SDETR1*COS(DG1)                         MM382960
       XTARG1 = XRNG1+XD1                                                 MM382970
       YTARG1 = YRNG1+YD1                                                 MM382980
       RTARG1 = SQRT(XTARG1**2+YTARG1**2)                                 MM382990
C                                                                         MM383000
       REACT = DELAY                                                      MM383010
       YY = VV*REACT                                                      MM383020
C                                                                         MM383030
CC                                                                        MM383040
CCC    ************************************************************      MM383050
CCCC   *                                                          *      MM383060
CCCCC  *    ** GENERATION OF TRUE MISSILE-POSITION AT LOCK-ON **  *      MM383070
CCCCCC *                                                          *      MM383080
CCCCCCC ************************************************************      MM383090
CCCCCCC                                                                   MM383100
CCCCCCC                                                                   MM383110
CCCCCCC                                                                   MM383120
       DO 590 KA=1,NA                                                     MM383130
C                                                                         MM383140
CCC                                                                       MM383150
CCCC                                                                      MM383160
       DO 580 KT=1,NT                                                     MM383170
C                                                                         MM383180
       RLAUN1 = (RPOA1-ACTIV(KA))+(TDEL(KT)-TLAUN)*VEXOC1                 MM383190
       XLAUN1 = RLAUN1*SIN(ZA1)                                           MM383200
       YLAUN1 = RLAUN1*COS(ZA1)                                           MM383210
       TFLIT1 = RLAUN1/VEXOC1                                             MM383220
       TLOCK1 = TFLIT1+TLAUN                                              MM383230
C                                                                         MM383240
C                                                                         MM383250
       CALL NORMAL (NLOCK,ZLOCK,2)                                        MM383260
       SLCKB1 = 1.62*TLOCK1*ZLOCK(1)                                      MM383270
       SLCKR1 = SLOKB1                                                    MM383280
       XL1 = SLCKB1*COS(ZA1)+SLOKR1*SIN(ZA1)                              MM383290
       YL1 = (-1)*SLOKB1*SIN(ZA1)+SLOKR1*COS(ZA1)                         MM383300
       XLOCK1 = XLAUN1+XL1                                                MM383310
       YLOCK1 = YLAUN1+YL1                                                MM383320
```

```
      RLOCK1 = SQRT(XLOCK1**2+YLOCK1**2)                                    MM383330
C                                                                           MM383340
CCC                                                                         MM383350
CCC   ************************************************************        MM383360
CCC   *                                                          *        MM383370
CCC   *                ** DECISION FOR FINAL COURSE **           *        MM383380
CCC   *   ** GENERATION OF TRUE TARGET-POSITION AT LOCK-ON **     *        MM383390
CCC   *                                                          *        MM383400
CCC   ************************************************************        MM383410
CC                                                                          MM383420
C                                                                           MM383430
      TIME1 = TLOCK1-REACT                                                  MM383440
      IF (TIME1.LT.0.0) TIME1=0.0                                           MM383450
      VV1 = VV+ACC*TIME1                                                    MM383460
      VV1FIN = AMIN1(V1MAX,VV1)                                             MM383470
      VV1AVG = (VV+VV1FIN)/2.0                                              MM383480
      IF (ACCTIM.GT.TIME1) GO TO 430                                        MM383490
      YR1 = VV1AVG*ACCTIM+(TIME1-ACCTIM)*VV1FIN                             MM383500
      GO TO 440                                                             MM383510
  430 YR1 = VV1AVG*TIME1                                                    MM383520
C                                                                           MM383530
C                                                                           MM383540
  440 CALL RANDOM (NTIME1,UTURN1,1)                                         MM383550
      IF (UTURN1.GT.0.9999) UTURN1=0.9999                                   MM383560
      IF (T9.GT.TIME1) GO TO 450                                            MM383570
      TT1 = UTURN1*T9                                                       MM383580
      GO TO 460                                                             MM383590
  450 TT1 = UTURN1*TIME1                                                    MM383600
  460 DELTA1 = TT1*TRNRTE                                                   MM383610
      D1 = DELTA1*RADIAN                                                    MM383620
C                                                                           MM383630
      TG1X1 = RADIUS*(1.0-COS(D1))+(YR1-RADIUS*D1)*SIN(D1)                  MM383640
      TG1Y1 = YY+RADIUS*SIN(D1)+(YR1-RADIUS*D1)*COS(D1)                     MM383650
      TG1X2 = (-1)*TG1X1                                                    MM383660
      TG1Y2 = TG1Y1                                                         MM383670
C                                                                           MM383680
      TG1X1R = TG1X1*COS(PSI)+TG1Y1*SIN(PSI)                                MM383690
      TG1Y1R = (-1)*TG1X1*SIN(PSI)+TG1Y1*COS(PSI)                           MM383700
      TG1X2R = TG1X2*COS(PSI)+TG1Y2*SIN(PSI)                                MM383710
      TG1Y2R = (-1)*TG1X2*SIN(PSI)+TG1Y2*COS(PSI)                           MM383720
C                                                                           MM383730
      TG1LX1 = XTARG1+TG1X1R                                                MM383740
      TG1LY1 = YTARG1+TG1Y1R                                                MM383750
      TG1LX2 = XTARG1+TG1X2R                                                MM383760
      TG1LY2 = YTARG1+TG1Y2R                                                MM383770
C                                                                           MM383780
CC                                                                          MM383790
C     ************************************************************        MM383800
```

```
C     *                                                              *      MM383810
C     *              ** DECISION FOR TURN-DIRECTION **               *      MM383820
C     *                                                              *      MM383830
CCCCC ****************************************************************      MM383840
C                                                                            MM383850
C                                                                            MM383860
      CALL RANDOM (NTURN1,UPOS1,1)                                           MM383870
      IF (UPOS1.GT.0.9999) UPOS1=0.9999                                      MM383880
      IF (UPOS1.GT.0.5000) GO TO 470                                         MM383890
      SIM1X = TG1LX1                                                         MM383900
      SIM1Y = TG1LY1                                                         MM383910
      GO TO 480                                                              MM383920
  470 SIM1X = TG1LX2                                                         MM383930
      SIM1Y = TG1LY2                                                         MM383940
C                                                                            MM383950
CCCCC ****************************************************************      MM383960
C     *                                                              *      MM383970
C     *              ** TEST FOR TARGET-ACQUISITION **               *      MM383980
C     *                                                              *      MM383990
CCCCC ****************************************************************      MM384000
C                                                                            MM384010
C                                                                            MM384020
  480 TAU1(KT) = ZETA1-THETA(KT)                                             MM384030
      TAU2(KT) = ZETA1+THETA(KT)                                             MM384040
      XTEST1 = SIM1X-XLOCK1                                                  MM384050
      YTEST1 = SIM1Y-YLOCK1                                                  MM384060
      R1 = SQRT(XTEST1**2+YTEST1**2)                                         MM384070
      G1 = ARSIN(XTEST1/R1)                                                  MM384080
C                                                                            MM384090
      IF (DEG1.LT.090.0) GO TO 500                                           MM384100
      IF (DEG1.EQ.090.0) GO TO 490                                           MM384110
      IF (DEG1.LT.270.0) GO TO 520                                           MM384120
      IF (DEG1.EQ.270.0) GO TO 510                                           MM384130
      IF (DEG1.LE.360.0) GO TO 530                                           MM384140
C                                                                            MM384150
  490 IF (SDETB1.GE.0.0) GO TO 520                                           MM384160
  500 GAMMA1 = G1*CF                                                         MM384170
      GO TO 540                                                              MM384180
  510 IF (SDETB1.GE.0.0) GO TO 530                                           MM384190
  520 GAMMA1 = (-1)*G1*CF+180.0                                              MM384200
      GO TO 540                                                              MM384210
  530 GAMMA1 = G1*CF+360.0                                                   MM384220
  540 IF ((GAMMA1.GT.TAU1(KT)).AND.(GAMMA1.LT.TAU2(KT))) GO TO 550           MM384230
      GO TO 580                                                              MM384240
C                                                                            MM384250
CCC                                                                          MM384260
C                                                                            MM384270
                                                                             MM384280
```

```
  550 DO 570 KL=1,NL                                                    MM384290
      RTEST1(KL) = ACTIV(KA)-(TDEL(KT)-TLAUN)*VEXCC1+L(KL)              MM384300
      RTEST2(KL) = ACTIV(KA)-(TDEL(KT)-TLAUN)*VEXC+1+L(KL)              MM384310
      IF ((R1.LT.RTEST1(KL)).AND.(R1.GT.RTEST2(KL))) GO TO 560          MM384320
      GO TO 570                                                         MM384330
  560 P(KK,KX,KA,KT,KL) = P(KK,KX,KA,KT,KL)+1.0                        MM384340
C                                                                       MM384350
  570 CONTINUE                                                          MM384360
C                                                                       MM384370
  580 CONTINUE                                                          MM384380
C                                                                       MM384390
C                                                                       MM384400
  590 CONTINUE                                                          MM384410
C                                                                       MM384420
C                                                                       MM384430
  600 CONTINUE                                                          MM384440
C                                                                       MM384450
C                                                                       MM384460
C                                                                       MM384470
      DO 610 KA=1,NA                                                    MM384480
C                                                                       MM384490
      DO 610 KT=1,NT                                                    MM384500
C                                                                       MM384510
      DO 610 KL=1,NL                                                    MM384520
C                                                                       MM384530
  610 PX(KK,KX,KA,KT,KL) = P(KK,KX,KA,KT,KL)/REAL                       MM384540
C                                                                       MM384550
C                                                                       MM384560
  620 CONTINUE                                                          MM384570
C                                                                       MM384580
C                                                                       MM384590
C                                                                       MM384600
      DO 630 KA=1,NA                                                    MM384610
C                                                                       MM384620
      DO 630 KT=1,NT                                                    MM384630
C                                                                       MM384640
      DO 630 KL=1,NL                                                    MM384650
C                                                                       MM384660
  630 PC(KK,KA,KT,KL) = (PX(KK,1,KA,KT,KL)+PX(KK,2,KA,KT,KL))/2.0       MM384670
C                                                                       MM384680
C                                                                       MM384690
  640 CONTINUE                                                          MM384700
C                                                                       MM384710
C                                                                       MM384720
C                                                                       MM384730
C     ************************************************************      MM384740
C     *                                                          *      MM384750
C     *              **          RESULTS          **             *      MM384760
```

```
C      *                                                                    *      MM384770
CCC    **********************************************************************      MM384780
C                                                                                  MM384790
C                                                                                  MM384800
       WRITE (6,170) ASP1,DEG1                                                     MM384810
       WRITE (6,180) ALFA1(K)                                                      MM384820
       WRITE (6,190) RANGE1(I)                                                     MM384830
       WRITE (6,200) POA                                                           MM384840
       WRITE (6,210) ZETA1,RPOA1                                                   MM384850
       WRITE (6,250)                                                               MM384860
       WRITE (6,220)                                                               MM384870
       WRITE (6,240) (AA1(KK),BEPTG1(KK),RLPEP1(KK),PD(KK,1,1,1),PD(KK,1,MM384880
      11,2),PD(KK,1,2,1),PD(KK,1,2,2),KK=1,NEPTG1)                                 MM384890
       WRITE (6,250)                                                               MM384900
       WRITE (6,230)                                                               MM384910
       WRITE (6,240) (AA1(KK),BEPTG1(KK),RLPEP1(KK),PD(KK,2,1,1),PD(KK,2,MM384920
      11,2),PD(KK,2,2,1),PD(KK,2,2,2),KK=1,NEPTG1)                                 MM384930
  65C CCNTINUE                                                                     MM384940
C                                                                                  MM384950
CC                                                                                 MM384960
  66C CCNTINUE                                                                     MM384970
CC                                                                                 MM384980
CC                                                                                 MM384990
  67C CCNTINUE                                                                     MM385000
CC                                                                                 MM385010
CC                                                                                 MM385020
  68C CCNTINUE                                                                     MM385030
CC                                                                                 MM385040
CC                                                                                 MM385050
       STCP                                                                        MM385060
       END                                                                         MM385070
```

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